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Back to the Future

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A multidisciplinary journal for patients and spine specialists

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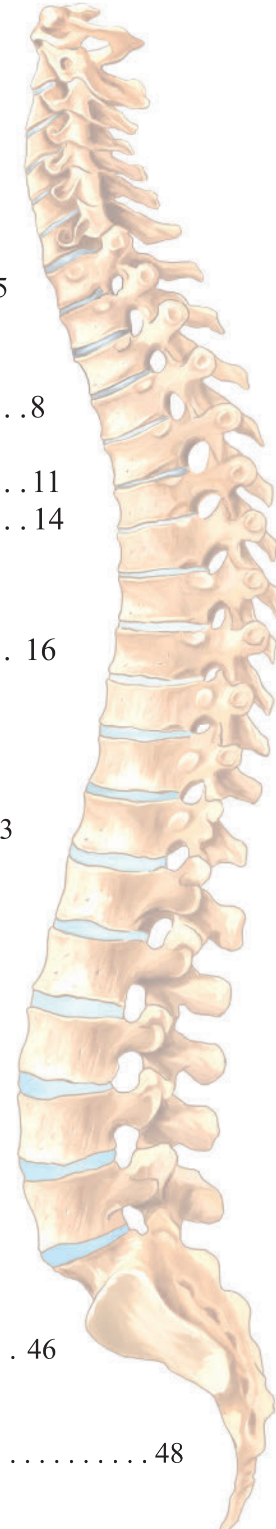


Special Focus: Back to the Future

From the Editor

Brian R. Subach, M.D., F.A.C.S.

In thinking about the title of this edition of the *Journal of the Spinal Research Foundation*, I decided that 'Back to the Future' was particularly relevant in our current handling of patient complaints, concerns, and issues. As scientists, we are focused on the treatment of disease; however, with our similar focus on technology, I believe we have lost our ability to listen to patients, identify their problems, perform reasonable physical examinations, and make diagnoses. We are concerned with what implant can be placed in the spine to make it new, and what type of technology can be used to revitalize a situation. We can place stem cells into a disc or joint to make it act like new again. Our imaging studies have become quite advanced, including special magnetic resonance imaging (MRI) sequences, which can show even fatty tissue inside the spinal canal.

I feel that 'Back to the Future' really sheds light on the fact that there is a disconnect between physicians and patients. I recently had a patient who complained that during her prior visit to an outside surgical provider, the surgeon sat with a laptop computer between them, frantically typing on the keys without even laying eyes on her. By interposing the computer screen between the doctor and the patient, what happens to the doctor-patient relationship? The trust that should exist between an expert and someone who is suffering, so that a plan and treatment can be formulated, is never established. In many cases, when asked who his or her doctor is, a patient will respond with the name of their primary care physician as opposed to the spinal health care provider.

Not only are electronic medical records contributing to the disconnect between patients and providers, but also the general push for technology. Recall that spinal surgery, both neck and back surgery, has been done successfully for the past sixty years. Our tendency as spinal health care providers is to forget what has worked in the past in favor of a new and improved treatment. For example, bone grafting from the patient's own hip has been proven to be an effective and safe means of accomplishing arthrodesis or spinal fusion. A fair number of people complain of discomfort from the donor harvest site, leading to a veritable explosion of alternatives. These bone graft extenders are produced by device manufacturers as a means of replacing the patient's own bone with an unproven substitute. These are typically calcium mineral composites, which have no clear proven efficacy other than simply resembling bone.

In a discussion with another patient recently, he asked why I wouldn't simply treat all three of the discs that appear black on an MRI scan. I explained that the MRI scan simply demonstrates the loss of water signal in the disc, but does not necessarily correlate with pain. If I operated simply based upon MRI scans, I anticipate I would be wrong half of the time. We often use adjunctive tests to give us additional proof, such as lumbar discography, which correlates the patient's actual pain pattern with the anatomy of the discs. Our reliance on imaging, such as free MRI scan reviews provided by the local laser surgery provider, have over-emphasized degenerative change in the spine without regard to the current pain generators.

In regard to the pain generators, nothing replaces a physical examination done by a spinal surgery expert. Pain in flexion (bending forward) or in extension (bending backward), pain on palpation over the spinous process or over the iliac wing, discomfort in the paraspinous muscles, or a clear step-off of the spinous processes—these are all unmistakable only in the hands of a spinal expert. One does not rely on an MRI scan for the diagnosis. One uses the MRI scan more as a confirmatory test.

I often hear that a spinal surgeon seeing a patient has recommended surgery. The patient had not undergone physical therapy or a trial of anti-inflammatory agents. There is no effort at core muscular strengthening or flexibility. I have a hard time understanding why a patient would consider surgery without first considering less aggressive options. I see hundreds of people that have had previous surgical opinions who have improved with physical therapy, some judicious corticosteroid injections, and overall health maintenance. I realize that exercise is difficult to recommend in a society which condones taking the easy way out, and where people are prone to morbid obesity. I cannot remember the last time, outside of my office, when a patient was counseled as to weight loss, nutrition, exercise routines, health maintenance issues, and promotion of general health.

The title of 'Back to the Future' means something a little different for me. I believe that spinal surgery and spinal health care are effective in changing people's lives. We are able to take away pain and restore people's functional capacity while focusing on the individual.

I am concerned, however, about our reliance on electronic medical records interposed between the doctor and patient; the push for technology at the expense of more time-honored interventions that work; the reliance on imaging while forgetting to examine the patient; the lack of physical therapy recommendation so that surgery becomes the only reasonable option; and finally, the lack of general counseling regarding weight loss, nutrition, and exercise which should be a part of every physician's responsibility and patient care. 'Back to the Future' means: let us take a step back and review what works. Our mission is to make people better, and that does not always mean doing it with some new and unproven technology.

From the President

Thomas C. Schuler, M.D., F.A.C.S.

Freedom Versus Equality and Its Impact on Spinal Health Care

America was founded on the principle of freedom. Our forefathers desired a chance to be free of the oppressive rule and taxation of the British government. Fortunately, they were successful in this endeavor and established a constitution guaranteeing freedom for all Americans, thus laying the foundation for equality of opportunity. In recent years, however, there has been a major push in our country's academic and political arenas to transform the definition of equal opportunity into that of equal outcome. It is important that we understand the stark difference between these two terms.

Equal opportunity is an essential component of freedom. All human beings are born free and equal in dignity and rights. They are endowed with reason and conscience, and their outcome will strongly resemble what they do with them. Equal outcome is very different. Regardless of what one does, the outcome would be the same as everyone else's—no better or worse. In order to accomplish equal outcome, it is essential to strip freedom. When our academic arena teaches young Americans that these terms are interchangeable, it is not surprising that the generations that follow are confused about what is beneficial for our country and its future. When our political arena makes equal outcome its goal—especially related to health care—the negative consequences are vast.

Ezekiel Emanuel, who is one of the engineers of the Obamacare legislation, was recently quoted as saying that he hoped to live a healthy life until he was seventy-five, and that would be enough for him. This is the fundamental basis of Obamacare: have Americans live healthy lives while they are young, minimizing consumption of health care resources, then die quickly once they become sick or old. The goal to produce equality in health care has been successful for the most part. The downfall is that this was achieved by reducing the quality and type of health care that insured Americans now have. Today, health insurance covers less and costs more for those who have private policies. In spinal health care over the past two years, there has been an increased length of time for authorization of procedures, as well as a vast increase in the number of procedures denied. Patients are suffering longer and many times without opportunity to have the insurance they purchased cover the most medically prudent and beneficial treatments. In hospitals across the country, volumes of spinal procedures are dropping. This decreased utilization is based upon poor economic policy and superimposed insurance changes that are stripping the freedom of choice from doctors and patients.

The goal of a centralized government and centralized health care system is that one size will fit all. That cannot be further from the truth in modern spinal health care. The benefit that we have today is that many of the technological advances that have occurred over the past two decades have enabled us to more precisely solve a very specific problem for a given patient. Not all spine problems are equal, and not all spine problems require the same treatment. The available surgical options can range anywhere from regenerative therapy and minimally invasive surgery to a more complex motion preserving operation such as arthroplasty. For others, a major surgical fusion would be the best fit. Factors such as the patient's health, body build, physical demands, and personal desires play an enormous role in identifying the optimal treatment for that given patient.

According to the third party payers, who are emboldened by the loss of patient's freedom caused by Obamacare, the patient and the doctor can no longer select what is in the patient's best interest. Instead, the patient and the physician must accept the care approved by a group that is financially incentivized to deny care. Consequently, not only do the patients suffer, but the engine for technological evolution is crippled through the denial of services in potential markets. If companies do not see opportunity for return, then they will not invest. We are already seeing the effects of this in the decline of medical research and development in both spinal health care and throughout the medical industry.

Plato wrote that in pursuit of justice "evil can be greater than the good." "Good" may be perceived as equitable medical care for all. The "evil" is Obamacare and the power it has given insurance companies to dictate medical care over the will of the patient or doctor. In pursuing equitable medical care, the government has actually created an inequitable and exploitative distribution of medical care and services.

As I have stated in prior presidential addresses, "health insurance does not equal health care." The American people have been mislead into thinking that by increasing the number of insured people, we would actually improve the health and well being of the population. While this is a noble aspiration, the implementation has created significant negative consequences. To continue down this road would be turning our backs on our founding principle of freedom, sealing a grim future for patients, providers, and the medical field as a whole. These attempts to equalize outcome are poisoning the founding tree of liberty.

Ask the Expert

David P. Rouben, M.D.

Q1: In your opinion, what is one of the most important advances in spinal health care since you began practicing spine surgery?

In the early 1980s, after completing my fellowship in Adult Spine Surgery, I began in private practice. I've been both an active creator, as well as a passive utilizer of new innovations in the surgical treatment of patients with spine problems. Before that time, spine surgeons would attach metal rods to the back of the spinal vertebral bones with metal hooks or attach screws and cables to the front of the spine column. The patients receiving these treatments were often bed ridden and immobilized for months at a time in body casts made of plaster. The multiple surgical wounds were long, often forming hideously thickened scars, relegating patients to wearing cover-all clothing for the rest of their lives. The psychological trauma associated with being bedridden in a body cast was often long-lasting.

But the 1990's saw a progression of new ideas designed to firmly stabilize one vertebra to another in a more consistent and effective manner, without the need for a body cast and long-term immobilization. Some surgeons attempted to attach the metal rods to the vertebrae with thick braided wire; some began inserting screws into the vertebral bones and then attached the rods; some attached plates with screws to the front and back of the vertebrae.

Stainless steel was the popular metal at the time, but there was a transition to titanium for a few reasons. Stainless steel was problematic because of allergenicity to the nickel in the metal. It was also very inflexible, and titanium acted more like the physical properties of our own bone instead of being so stiff.

Some of these ideas from the 1990's worked, and some didn't, but that's the nature of scientific innovation, and we persevered. However, the scientific community still wasn't satisfied. Patients and surgeons were frustrated with the poor success rates of spinal fusion, which often was no better than 80 percent, and we wanted to do better. Innovation is driven by the need to improve our results and the goal we have to make our patients better.

By the new millennium, spine surgeons began to focus on the concept of postural balance between the front and the back of our spines, believing that a balanced spine with good posture would be the best way to experience a pain-free, post-operative result. Just like building a stable support wall for any structure, spine surgeons began to appreciate that both the front and the back of the spine had to be supported and secured. To accomplish that goal, we witnessed the introduction and evolution of cage-disc spacers, metal or plastic fusion implants that were inserted between the ~~boney~~ spinal vertebrae to keep the spinal column from collapsing and bending. In an attempt to replicate the normal disc-vertebra motion, the presentation of artificial disc replacements was touted to re-establish normal function to diseased discs. We're still trying to perfect that project.

It seems as though the evolution of new and more progressive spine care treatments is as inevitable as change itself.

"It seems as though the evolution of new and more progressive spine care treatments is as inevitable as change itself."

Our system of health care delivery is also dramatically changing. There simply is not enough money to pay for all of those who need health care at the same level that we've enjoyed over the past 30 years. Health care will parcel out treatments based on confirmed scientific research. This research will guide us towards the appropriateness of health care treatment options and techniques with positive reproducible outcomes. The costs must be affordable, effective, and capable of consistently delivering the patient back to a functional productive lifestyle.

Patients will determine what will or will not be used as a treatment, based on their ability to return to a pre-injury level of quality productive activity. We must be able to evaluate and assess the cause of the underlying pain-producing disease condition, prescribe a treatment protocol that will be inexpensive, and produce a final result that will return the individual back to as normal a level of productivity as possible. That is our goal.

Q2: How have advances in minimally invasive surgical approaches impacted your practice?

For a little over ten years, spine surgeons have been treating their surgical patients using specific techniques that intentionally protect muscle, tendon, ligament, and bone tissue from unnecessary damage and harm. There was a commitment to only do exactly what was necessary to fix the patient's problem, without inadvertently damaging the adjacent tissue structures. This commitment was a deviation from the status quo. Its motivation was to improve patient outcomes.

There was a belief that spine surgeons could do better. We wanted our patients to experience less pain, avoid permanent disability or compromised physical function, and to return to their pre-treatment level of functional activity, sooner than in the past. Spine surgery should be able to deliver outcome improvements that include a speedier, more consistent return to pre-treatment status, while reducing overall treatment costs and returning patients to an independent functioning lifestyle.

Spine surgery patients can now avail themselves of surgical treatments that minimize tissue damage while alleviating the root cause of the source of disabling spine pain. These techniques, for better or for worse, are popularized by marketing experts as "Minimally Invasive Surgery-MIS" or "Minimal Access Surgery-MAS." No matter what these techniques are called, the primary goal is to minimize the damage of tissues that don't need to be damaged and still resolve the patient's problem.

"Spine surgery patients can now avail themselves of surgical treatments that minimize tissue damage while alleviating the root cause of the source of disabling spine pain."

We have and continue to study research that collects patient outcome data and compares the more traditional surgical approaches and techniques of spinal surgery to the newer minimally invasive techniques. Patients should expect to get back to work and back to play in less time, allocate lower costs for these procedures, and avoid returning to their surgeon for additional or repeat treatments.

Q3: Why is clinical research crucial to advancing spinal health care?

As with the past, the future will be determined by careful and unbiased scientific comparisons of differing approaches to solving a problem. The reality of today will force both the patient and the health care provider to push even harder to find ways to fix our problems and overcome whatever is impeding our ability to be independent, functioning individuals who can provide for ourselves and for others. We must compare and contrast what works and what doesn't. Research is the only way to get the answers to the questions we will be forced to resolve.

Q4: What can spinal patients do to become more knowledgeable about the latest treatment options in spinal health?

The internet is the library of today. By accessing the websites of the national spine care specialty societies and reading and comparing what treatments are available, the prospective spine patient of today will be better prepared to be an integral participant in his or her own treatment decisions. Talk to previous patients. Review the patient-based assessment evaluations of physicians and procedures on the internet. Avoid glitzy, eye-catching, cure-all claims by advertisers; if they didn't need to advertise to get business, they wouldn't.

"Avoid glitzy, eye-catching, cure-all claims by advertisers; if they didn't need to advertise to get business, they wouldn't."

David P. Rouben, M.D.

Dr. Rouben is a well-respected orthopedic spine surgeon who has been practicing in Louisville, KY for more than 20 years. He is the founder of River City Orthopedic Surgeons PSC, now known as Norton Spine Specialists—Rouben & Casnellie. As part of his practice, Dr. Rouben continues to provide the most up-to-date neck and back evaluation and treatment. His commitment to patient care includes assessing adult spinal pain, diseases and deformities, and offering nonsurgical and surgical treatment options to meet patients' expectations. Dr. Rouben has played a key role in the development of minimally invasive spinal surgery techniques and continues to innovate and develop new techniques, traveling around the globe to train spinal surgeons how to master them.

Spine Tale
David McKee

Brian R. Subach, M.D., F.A.C.S.

I am an active seasoned citizen (72 years old) who retired from the military and then taught high school math for 15 years at South Lakes High School and McLean High School. I am now fully retired, and part of my routine includes a workout in the gym once a week by warming up on a treadmill for 10 minutes, lifting an accumulation of 20,000 pounds, then riding a stationary bike for 25 minutes. Additionally, I play tennis and/or golf once a week, and occasionally I volunteer with both Habitat for Humanity and Food for Others. All of my activities require some strength and flexibility.

About three years ago, I started to have occasional numbness in my right arm and thumb. This was an annoyance, but the numbness was temporary, and I could still do almost everything. I also had strange neck cramps for no apparent reason. Then at the beginning of this year, my whole right arm hurt and became numb whenever I looked up. This progressed with the pain and numbness occurring frequently just looking straight ahead. Luckily, I could relieve my symptoms by putting my chin to my chest for a few seconds. It was almost comical to watch me lowering my head at strange times to alleviate the pain, but less comical when I was driving a car.

I did a lot of research, consulting many sources to determine the very best doctors in spinal problems to include spinal surgery. This is when I came to Dr. Subach at the Virginia Spine Institute for help. Dr. Subach recalls his evaluation of my spine in early 2014:

> BS: I first met Mr. David McKee in February 2014. This retired Army officer presented as a referral from the doctors at Walter Reed Army Medical Center. Prior to developing neck pain and right arm numbness, he had been very active. He found that his symptoms were worse when he looked up and felt that his pain limited everything that he tried to do. He described a distribution of 30% neck pain and 70% arm symptoms. His symptoms were truly relieved by forward flexion, and he noticed some weakness in his deltoid musculature, as well as a dull ache in his upper arm and a tingling sensation in his lower forearm. He described his pain as a 4 out of 10 on a Visual Analog Scale.
>
> His imaging studies included both x-rays and an MRI scan. The x-rays showed a posture which was slightly forward flexed. He had evidence of degenerative arthritis at multiple levels and a relatively stiff spine on flexion and extension bending views. The MRI scan of the cervical spine demonstrated two areas of compression, specifically of the nerves exiting the spine and headed down his right arm.
>
> Obviously, physical therapy would be somewhat helpful, but my concern was about the weakness. Someone having evidence of an irritated nerve may present as pain or numbness, but with overt weakness, my concern was loss of function. I ordered an EMG of his arms to see if there was any evidence of nerve damage. The nerve test dem-

Figure 1. Preoperative lateral plain x-ray of the cervical spine showing prominent degenerative changes with disc space collapse and bone spur formation at C5-C6 and C6-C7.

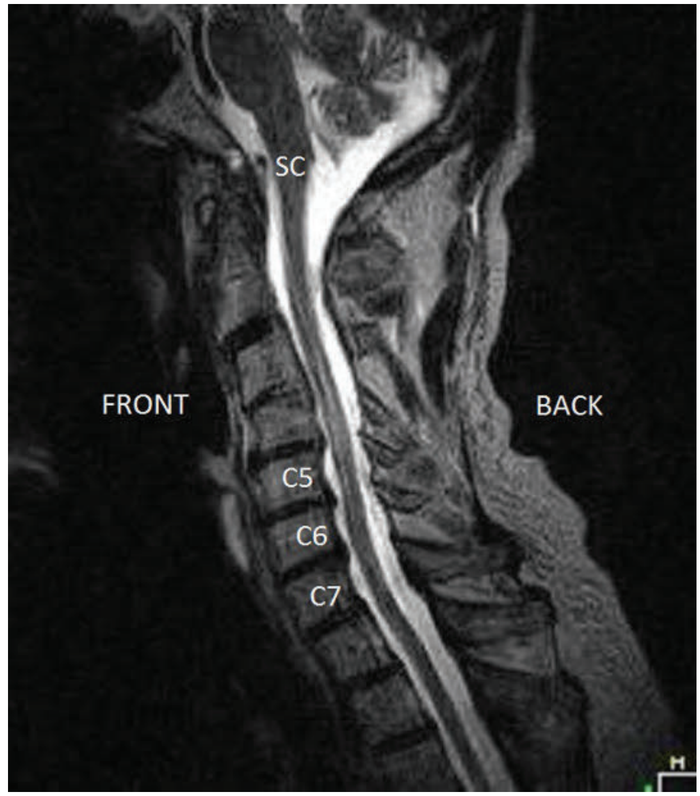


Figure 2. Preoperative T2-weighted sagittal (side view) MRI of the cervical spine with the patient facing to the left. Degenerative changes with disc herniations and bone spurs indenting the fluid space surrounding the spinal cord (SC) at the C5-C6 and C6-C7 levels.

> onstrated signs of moderate nerve damage which appeared to be chronic, involving both the C6 and C7 distributions. In essence, there was no evidence of progressive or ongoing nerve injury, but he had clearly sustained some degree of damage.
>
> After he completed a course of physical therapy and we had a chance to review the nerve study, we decided that he was not comfortable with the degree of neck pain and upper extremity symptoms, and he wished for some relief. We discussed an anterior cervical fusion (arthrodesis) where the degenerative discs are removed, replaced with a small wedge of donor bone, and then a titanium plate is fixated across the front of the spine to promote the healing process.

I tried the obligatory injections and physical therapy remedies, but they were ineffective. Dr. Subach dutifully explained that there were no guarantees with surgical remedies, and I think he was hesitant to perform surgery for someone my age, but I was almost desperate and maybe persuasive. On the 16th of April 2014, Dr. Subach performed surgery on my cervical spine at Reston Hospital Center:

> BS: In an operation lasting approximately one and one-half hour, Mr. McKee underwent anterior cervical fusion at both the C5/C6 and C6/C7 levels. There were significant bone spurs that were encroaching on the right-sided arm nerves, as well as indenting the spinal cord. He had an excellent operation with complete decompression of the spinal cord and the arm nerves on both sides. He stayed overnight in the hospital and then was discharged to home.

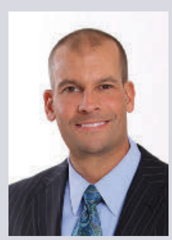
Figure 3. Postoperative lateral plain x-ray of the cervical spine showing anterior cervical fusion at C5-C6 and C6-C7 using donor bone (DB) and titanium plate (TP) fixation with screws into bones C5-C6-C7.

When I saw him back approximately two weeks after surgery, he had some mild right-sided neck pain, but the tingling that had been present previously in the right arm had resolved. We started a course of physical therapy and gave him some muscle relaxers to try to calm down the muscle spasm he was having. By July 29, 2014, three months after his anterior cervical fusion, he was happy. He was having no discomfort and no symptoms into his right arm, despite the EMG test showing permanent nerve damage prior to surgery. By taking the pressure off of the nerves and stabilizing the spine, the degenerative arthritis, which was primarily causing neck pain and the irritation of the exiting nerve roots, had been stabilized. He was pleased with his progress, and at only three months after the surgery, his imaging studies were already showing signs of healing.

I asked Mr. McKee to be a Spine Tale because of his outstanding recovery in the early postoperative period. I explained to him that it generally takes about one year for the fusion to completely heal, and many times it can take up to two years for the nerve endings to improve. He has made an outstanding recovery to this point!

The operation was an amazing success. I'm back in the gym, back on the golf course, and back on the tennis court. Believe it or not, my tennis game is even improved-maybe because of increased flexibility. I have also returned to my other volunteer activities. And, yes, I can look at the ceiling without consequence.

"The operation was an amazing success. I'm back in the gym, back on the golf course, and back on the tennis court."



Brian R. Subach, M.D., F.A.C.S.

Dr. Subach is a spine surgeon and the President at the Virginia Spine Institute. He is a nationally recognized expert in the treatment of spinal disorders and an active member of the American Association of Neurological Surgery, the Congress of Neurological Surgeons, and the North American Spine Society. He is an invited member of the international Degenerative Spine Study Group and a Fellow in the American College of Surgeons. He lectures extensively regarding the management of complex spinal disorders in both national and international forums. He is the Director of Research and Board Member for the non-profit Spinal Research Foundation and Editor-in-Chief of the *Journal of the Spinal Research Foundation*. He has written 15 book chapters and more than 50 published articles regarding treatment of the spine.

Spine Tale
Jim Winters

Richard A. Banton, P.T., D.P.T., O.C.S., C.M.P.T., A.T.C., and Jason W. Arnett, M.S., A.T.C., P.E.S.

Figure 1. My Mountain Staff, left to right: Matt, Aaron, Grace, Myself, Josh, Dan. Photo by Nathalie Theodorakoglou

My head was spinning and my vision was flickering as I lay on the ground hoping to remain conscious following a 15-foot fall from a ladder in the back yard of my home. After things settled down a bit, I tried to get up but was unable to walk due to the severe pain in my pelvis region and lower back. The ambulance ride was painful, but then came the real pain: being moved around for x-rays at the hospital. As long as nobody touched me and I remained perfectly still, I was OK. Bottom-line, I had three fractures to my pelvis and fractured my lower vertebrae (L1-L4).

I sought treatment right away, beginning with an orthopedic specialist and a neurosurgeon. Then I was referred to a pain control specialist and sought treatment at the Virginia Therapy and Fitness Center (VTFC) for evaluation. Initially, I was fitted with a "clam shell" brace that I had to wear full-time for the first several weeks. It seemed to hold all the fractures in place, thereby reducing the pain when I moved. I received several weeks of at-home occupational therapy to get me up and moving. I began by using a walker, graduated to crutches, and finally transitioned to a cane. I was moving slowly with a cane when I first came to see Rich Banton for evaluation at VTFC:

> RB: Jim was originally referred to me for a Functional Capacity Evaluation (FCE) to determine if he could safely return to his job as a project manager. During this evaluation, I concluded that Mr. Winters could not safely return to his job at the time, but I felt that I could help him achieve more functional ability and alleviate his pain. Jim had been in physical therapy at another facility for a few months, but they were focusing on exercises only. I knew that with good manual therapy, dry needling, and therapeutic exercise from Jason Arnett and me, we could enhance Mr. Winters' quality of life and possibly help him get back to work.

I ended up on short-term disability, then long-term disability, and eventually was laid off by my employer. The financial sky was falling, and there was nothing that I could do about it except continue to work at getting my strength and flexibility back, so that I might someday return to work. With job search time included, I ended up being unemployed for a total of 16 months after the initial fall from the ladder.

> JA: Our first goal was to help restore Jim's range of motion in his hips and spine. We accomplished this by using gentle spine range of motion exercises and functional movement patterns like squats and lunges. We progressed to balancing activities, core endurance training, and finally, functional re-training exercises.

> RB: For the next three months, we worked together two to three times per week on increasing his rib and thoracic spine mobility, reducing his muscular tension through dry needling and joint mobilizations, and improving his aerobic ability. As Jim's spine mobility was restored, his posture improved and thus reduced the abnormal forces on his compression fractures in his lumbar spine. Jim's pain was decreasing, and this enabled him to walk further, tolerate sitting longer, improve his material handling ability, and eventually return to the job he loved.

Almost one year and a half later, re-injury occurred. WHAP! I had slipped on a wet ramp and lay flat on my back, looking up at the cold mountain rain. This time the pain was severe in the area of my mid-back. "Not again," I thought to myself. I had just completed healing from the first fall and had returned to work part-time. This second fall was at my mountain property 200 miles from home. I was by myself, and my cell phone was in the truck. As I made it to my feet, I surmised that my pelvis was OK, so I was able to pull myself into the truck and headed for home. After driving for 90 minutes or so, the bumps in the road of Route 81 caused excruciating pain in my mid-back. The gas tank was on empty, and I knew that I would be unable to get out of the truck by myself to refuel. So I drove to the hospital in Woodstock, VA and waited for an ambulance crew to help me get out of the truck and into the emergency room. I had fractured my T8 vertebra and had lots of bruising to my mid-back.

> **"The VTFC treatment made a significant contribution to restoring my life and my livelihood. For a 64-old "kid," I'm doing much better than I would have believed possible after incurring ~~fractured~~ pelvis and vertebrae."**

This second injury was a big concern, but recovery time for getting back to work was much quicker. This time, Rich's dry needling work really made a huge difference. A blend of the dry needling and the physical therapy was just the right medicine to get me back in the saddle fairly quickly.

> JA: For Jim's second go around, after his slip at the cabin, he was pretty flared up. We began with pain-controlling modalities like cold laser, electrical stimulation therapy, and cryotherapy. Once his pain was under control, we jumped back into the core endurance training exercises that Jim was so fond of from his previous time here.

At VTFC, Rich would periodically do a reassessment of my progress after working with Jason. Jason's inspiring expertise was crucial to my ability to complete essential exercises and stretches without re-injuring me. I would not have recovered to the extent that I did, were it not for Rich Banton and Jason Arnett's expert help. Obviously, I am grateful beyond words.

Figure 2. With my heroes: Rich Banton (left) and Jason Arnett (right).

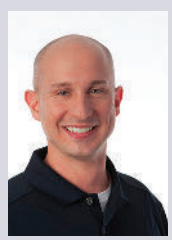
The VTFC treatment made a significant contribution to restoring my life and my livelihood. For a 64-old "kid," I'm doing much better than I would have believed possible after incurring fractures to my pelvis and vertebrae. I'm able to walk long distances with no trouble and have no need for a handicapped parking placard anymore. I'm grateful for the return of my strength and stamina, but it took work (lots of good sweat) with the physical therapy experts at VTFC. The VTFC staff of professionals really know what they're doing to restore as much of your functionality as possible. They work to your level of tolerance, making progress each session; they listen carefully to any concern you have; they do excellent and timely reporting to your regular physicians and specialists; and, while it's tough to quantify, the entire VTFC staff offers good-natured encouragement at every turn. I am so glad that Rich, Jason, and the VTFC staffers were there for me—for both of my falls.

"It took quality physical therapy and exercise to improve Jim's function, but it took much more heart and will power from Jim to push through the pain and the slow healing process to get back to where he is today."

RB: Jim is the best patient. It took quality physical therapy and exercise to improve Jim's function, but it took much more heart and will power from Jim to push through the pain and the slow healing process to get back to where he is today. In addition to almost losing a job that he had done for over 20 years, Jim also had a more important job at home. Jim has a son with special needs, and for the first time in his life, he feared that he may not be able to take care of his son because his functional limitations. It is often said that physical therapists inspire their patients, but in this case, Jim inspired me. He is one of the most genuine and kind people you will ever meet, and he has a will to succeed that is unmatched. I know that I helped Jim, but he helped me too.

Richard A. Banton, P.T., D.P.T., O.C.S., C.M.P.T., A.T.C.

Richard Banton has served as Co-Clinic Director for Virginia Therapy and Fitness Center since its inception in 2004. He has been practicing physical therapy since 1998, working with a variety of orthopedic, neurologic, and pediatric conditions. Rich's education paired with the latest training and knowledge of advanced techniques in physical therapy has established him as dynamic leader in the field. His extensive experience includes the treatment of athlete from the high school to collegiate and professional levels; including Olympic athletes, Washington Redskins football players, and other athletes from NASCAR and the LPGA. Rich's dedication to continuing education finds him teaching course work through the Institute of Advanced Musculoskeletal Treatments (IAMT).



Jason W. Arnett, M.S., A.T.C., P.E.S.

Jason Arnett is a certified athletic trainer at the Virginia Therapy and Fitness Center. His approach with each patient is to develop an individualized comprehensive rehabilitation program that meets the patient's goals while maximizing potential and reducing risk of injury. Jason incorporates a combination of flexibility, balance, core training, and integrated multiplanar resistance training for his patients. Additionally, Jason's research interests include balance and postural stability and psychology of the injured athlete.

Spine Tale
Linda Watson

Justin S. Field, M.D. and Susan D. Parker

The first time I started feeling low back pain was approximately five years ago. As I work in a medical office that deals with pain of all kinds, I am used to seeing debilitated patients. It was hard to continue at work with my back and leg pain and not show it to our patients that were also feeling helpless with pain.

Every day was difficult; every weekend was ruined by pain and kept me from enjoying my family. For several years, I went through physical therapy, facet injections, epidural steroid injections, and trigger point injections. For awhile, they would provide relief, but the pain would come back. I had complete faith in my doctor who managed my pain, and when he finally said it was time to see a surgeon, I knew he would steer me in the right direction. I was ready for the next step. I met with Dr. Justin Field who was able to treat my spine pain:

JF: Linda is a very active and vibrant woman who had been suffering from back and leg pain for many years. Besides being athletic and exercising regularly, she manages a very busy and reputable pain management and physical therapy practice. As her back and leg pain worsened, an MRI showed she had a Grade 1 dynamic spondylolisthesis at L4-L5 with moderate to severe stenosis. Linda received several epidural injections which gave her relief, but unfortunately for only a short duration of time. Linda had seen many of my patients get better after surgery and was hoping I could get her better. Because of her dynamic spondylolisthesis at L4-L5, I felt the best surgery for her would be a one-level minimally invasive posterior decompression and fusion. Linda did very well after surgery and has continued to be an inspiration to all the patients that come through her office.

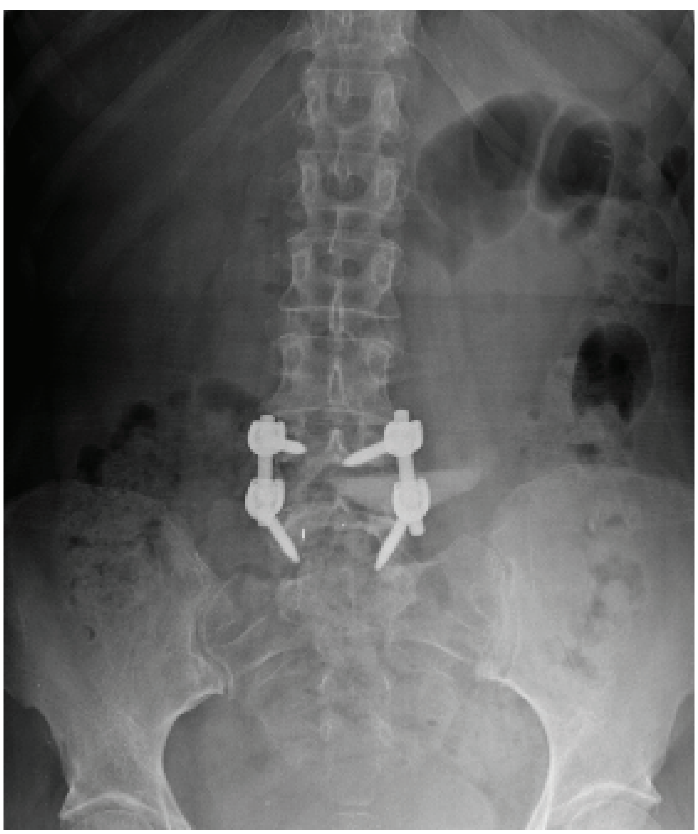


Figure 1. Anteroposterior view of postoperative x-rays following a fusion at the L4-L5 level.

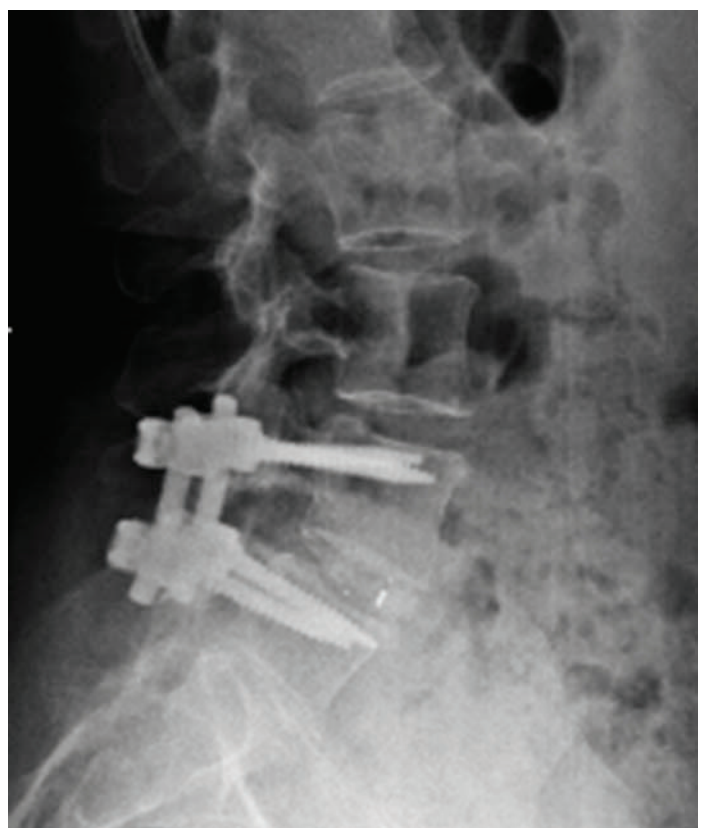


Figure 2. Lateral view of postoperative x-rays following a fusion at the L4-L5 level.

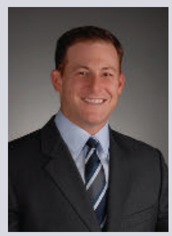
I saw Dr. Field at an open house not long after surgery, and he asked me how I was feeling. My response was, "It's like being able to breathe again, to take a deep breath and just breathe again." That is something I had forgotten to do, as I am sure many others have. I felt more relaxed and had more energy, with more to look forward to. Today I go to the gym five days a week, take yoga, go hiking, and talk to people about how they are feeling because I know how helpless they feel when their pain seems endless.

"I saw Dr. Field at an open house not long after surgery, and he asked me how I was feeling. My response was, "It's like being able to breathe again, to take a deep breath and just breathe again.""

My advice to anyone going through this type of pain is first try your passive treatments, trust your doctor, and when nothing works and your doctor suggests seeing a surgeon, DON'T hesitate; life is too short to live in pain. Then, go out and live! I appreciate all my doctors who have made a difference in my life, thank you.

Linda Watson and Dr. Field at the "We've Got Your Back" race for spinal health.

Justin S. Field, M.D.



Dr. Field is a board certified, fellowship trained orthopedic spine surgeon at the Desert Institute for Spine Care. Dr. Field has specialized training in minimally invasive spine surgery and motion sparing technologies, such as cervical and lumbar artificial disc replacement as well as non-fusion stabilization. In addition, he has extensive training in adult deformity correction and treatment. Dr. Field earned his medical degree at Tulane University, where he finished in the top 1% of his class. He completed both his surgical internship and orthopedic surgery residency at Duke University and completed a spine surgery fellowship at The Spine Institute in Santa Monica, CA. Dr. Field was recognized by his peers to be one of the top Phoenix spine surgeons in 2009, 2011, 2012 and 2013. He was also recognized as one of *America's Most Compassionate Doctors*.

Susan D. Parker

Susan Parker is the Director of Marketing at Desert Institute for Spine Care (DISC), a spine surgery practice in Phoenix, Arizona. She specializes in business development, strategic partnerships, sales, and marketing. Susan has spent the majority of her career in biologic and medical device sales, often chosen for national task forces and leadership roles in training and mentoring peers. Her experience includes regional, national, and international sales and marketing for Johnson & Johnson, Sanofi-Synthelabo, Reebok International, and Desert Institute for Spine Care. Named a Marketing Expert in the Worldwide Who's Who in 2012, Susan is passionate about using her skills and expertise to help patients find pain relief at DISC.

From Your Athletic Trainer
Breaking Down the Exercises that Break Down your Spine

Jason W. Arnett, M.S., A.T.C., P.E.S.

Most people will experience a bout of low back pain at some point in their lives. Often, the cause of the low back pain is misunderstood, and efforts to relieve the low back pain are misdirected. Many awake in the morning with low back pain or tightness, attributing the pain and/or tightness to "sleeping on it wrong," not knowing the cause of the pain was an accumulation of events that have been occurring over the course of the past few months or even years. Clinicians and patients alike will often attribute low back pain to an event, e.g., a sneeze or a bad night's sleep. Yet very few back injuries occur from a single event, often misguiding efforts to deal with the real cause of the cumulative trauma.[1] The key to optimal performance or rehabilitation is injury avoidance, and this requires an understanding of the biomechanical principles of tissue loading and subsequent adaptation or degradation. Too many good backs are ruined by inappropriate training that follows current fads or traditional strength training regimens without understanding the biomechanics of the spine. The purpose of this article is to discuss the low back injury mechanisms causing excessive tissue loading and eventual tissue failure as related to common core exercises.

> "Clinicians and patients alike will often attribute low back pain to an event, e.g., a sneeze or a bad night's sleep. Yet very few back injuries occur from a single event, often misguiding efforts to deal with the real cause of the cumulative trauma."

In general, biological tissues respond to loading stress as a U-shaped function. Too little stress will not stimulate tissue adaptation, and too much stress will overload tissue leading to injury. The optimal load is not too much, not too little, and is unique to the individual. An exercise that builds one individual may overwhelm another.

Injury Process

Injury occurs when an applied load exceeds the tissue tolerance. A load that is great enough and applied once can certainly result in an injury, e.g., a fall. More common, however, is the repeated submaximal load causing injury. Submaximal loads can be repeated or sustained. Repeated loads cause tissue fatigue, reduce tissue tolerance, and lead to failure on the Nth repetition, resulting in injury.[1] Sit-ups, Russian twists, and back extensions are excellent examples of repeated loading.

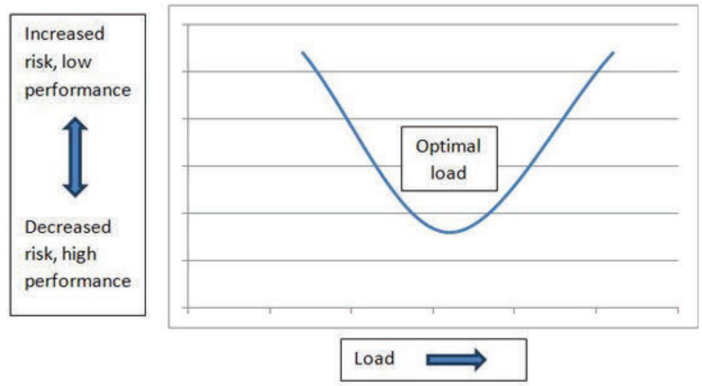


Figure 1. Risk of injury and level of performance in relation to load level. *Image adapted from* McGill, S. (2006) Ultimate Back Fitness and Performance. Waterloo: Backfitpro Inc.

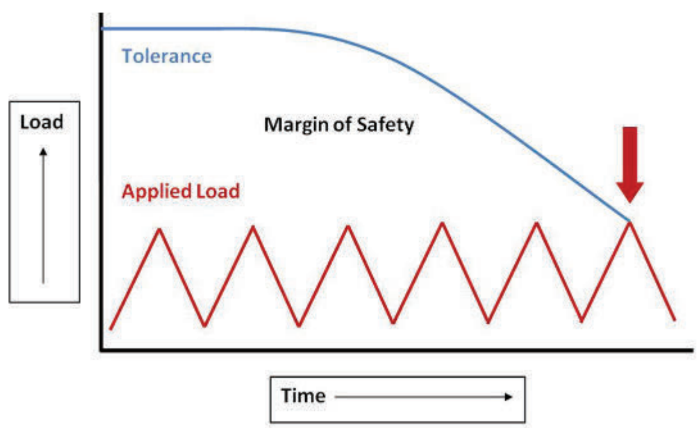


Figure 2. Repeated loads lead to failure over time. *Image adapted from* McGill, S. (2006) Ultimate Back Fitness and Performance. Waterloo: Backfitpro Inc.

Sustained loads over a period of time cause tissue to slowly deform, leading to a reduction in tissue strength and resulting in injury.[1] Sustained postures such as sitting and spine stretching are examples of sustained loads.

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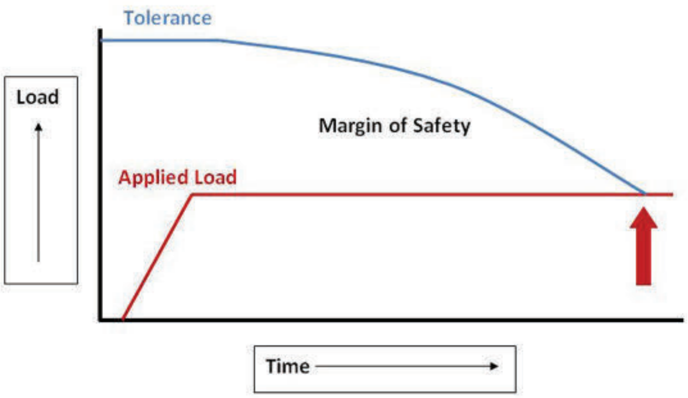

Figure 3. Sustained load leads to failure over time. *Image adapted from* McGill, S. (2006) Ultimate Back Fitness and Performance. Waterloo: Backfitpro Inc.

Tissue loading is necessary for optimal tissue health. When loading and subsequent degradation of tolerance is wisely followed by a period of rest, an adaptive tissue response increases tolerance.[1]

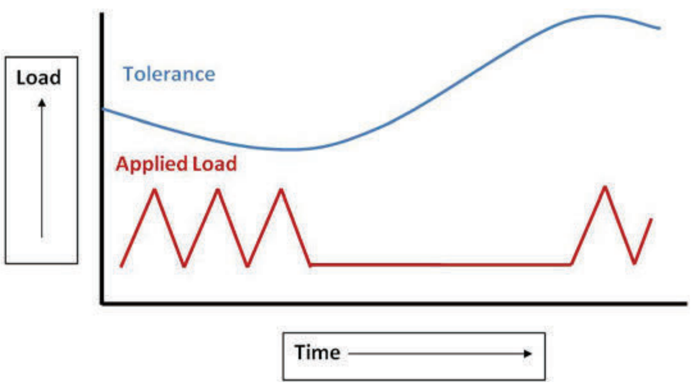

Figure 4. Proper amount of load followed by rest increases tolerance. *Image adapted from* McGill, S. (2006) Ultimate Back Fitness and Performance. Waterloo: Backfitpro Inc.

It is important to note that tissue damage may not outwardly appear as swelling or even pain. Submaximal micro trauma of tissue will cause inflammation that can result in a muscle spasm, where the individual will experience a feeling of tightness in the low back. Muscle spasms are born out of the inflammatory process, and they are a signal of significant tissue damage. This tightness is often the first real sense of something wrong. As you will see, the common yet misguided efforts to relieve the low back tightness, e.g., low back stretching, can actually lead to even more trauma. Scientific principles of tissue loading and response to injury must be considered during exercise design whether it is for increased performance, general fitness, or rehabilitation.

Mechanisms of Injury

Understanding the biomechanics of the spine and injury mechanisms of spinal tissue is important for injury avoidance and improved performance. Functionally, the muscles of the arms and legs and the hips and shoulders are designed to create movement throughout a range of motion. The muscles of the spine, however, are designed to create stiffness, stop movement, and transfer the power generated in the hips and shoulders.

Figure 5. Pitcher CJ Wilson of the Los Angeles Angels of Anaheim exhibits perfect form during a pitch, demonstrating the use of the muscles in his shoulders and hips to create movement, while keeping a stiff spine to transfer the power generated in the hips and shoulders. *Image source:* Jeff Gross/ Getty Images North America.

With the injury process in mind, you will see in the subsequent sections that training the spine through its range of motion, as done with common exercises, will result in deleterious and irreversible damage in spinal tissue decreasing function and performance.

Spine Flexion

As the spine flexes (bends forward, flattens, or rounds), several tissues are at risk of injury. Muscles provide support for the spine as it begins to flex; however, as the spine approaches full flexion, the support responsibilities shift away from the muscles and onto the intervertebral discs and ligaments. Posterior disc herniations are associated with repeated flexion of the spine and/ or a sustained flexed posture. Evidence of the process of disc herniation is repeated lumbar flexion with very little load. Callaghan and McGill (2001) consistently created disc herniations with modest load in the neighborhood of 22,000–28,000 cycles of flexion. Not surprisingly, with increased loads the number of flexion cycles required to cause a disc herniation decreased to 5,000–9,500. More recently, Tampier (2007) and Veres (2009) confirmed that the greater the load and the more repetitions, the faster a herniation will occur. Recall the tissue loading response in the previous section where the repeated submaximal trauma to the discs is occurring unbeknownst to the future patient. This has enormous implications when designing an exercise program.

The interspinous ligament is also at risk of injury during spine flexion. This ligament, once believed to prevent excessive spine flexion, actually prevents posterior shear of the above vertebra.[6] However, as the spine flexes, the oblique orientation of the interspinous ligament imposes an anterior shear on the above vertebra. This anterior shear stresses the interspinous ligament, among others, and reduces the shear tolerance of the spine. An osteoligamentous spine (a spine devoid of muscle) collapses under 20 lbs; that is all the load ligaments can tolerate. In full flexion, not only are discs at risk of injury, but shear is greater, putting the ligaments at risk as well.

Spine Flexibility

Stretching the spine often involves flexing it, e.g., touching the toes or pulling the knees to the chest. Therefore, a discussion regarding spine flexibility will be included in this section.

There is a popular notion that more spine flexibility is necessary for a healthy spine. The scientific evidence would disagree. In fact, the more flexibility one has in the spine, the greater risk one has of having low back troubles.[7,8,9] Sullivan et al. (2000) found no correlation in lumbar range of motion and low back pain. Parks et al. (2003) demonstrated that spine range of motion has little to do with functional activities such as walking, standing, sitting, pushing, pulling, lifting, and carrying. Solomonow (2003) has shown that static stretching of the spine ligaments can cause muscle spasms and can diminish the stretch reflex; a reflex that is protective! Recall that muscle tightness accompanies the inflammatory process. Lastly, Snook and colleagues (1998) proved that simply removing spine flexion from morning activities decreased pain and improved function. Based on the scientific evidence, having a flexible spine does not ensure spine safety. In fact, it ensures quite the opposite. Those rehabilitating from a low back injury or those concerned with preventing low back injury would be wise to focus on deficits other than spine flexibility.

> **“There is a popular notion that more spine flexibility is necessary for a healthy spine. The scientific evidence would disagree.”**

So the question becomes, where, how, and why did spine range of motion become the gold standard for measuring ability, disability, and function? To quote McGill (2002):

> “Lawyers and compensation boards need numbers for the purpose of defining disability and rewarding compensation . . . and range of motion is objective and easily measured. The current metric for determining disability appears to have been chosen for legal convenience rather than for a positive impact on low back trouble. The current landscape creates a reward system for therapy that arguably hinders optimal rehabilitation.”

Although beyond the scope of this article, a safer, more functional, and the most spine-sparing approach to decreasing viscosity (stiffness) and maintaining one's range of motion in the spine is through active flexibility. The cat/camel is a motion exercise, where emphasis is placed on motion rather than pushing (stretching) into passive tissues.

Implications of Spine Flexion on Exercise

Any repetitive exercise, with or without load, where the lumbar spine is allowed to flex, round, or flatten, will over-stress the discs and ligaments. Recall that this is a submaximal cumulative effect, where trauma is occurring without any forewarning. Sit-ups produce large shear and compressive forces on the intervertebral discs and across the lumbar spine.[14,15,16] Increased muscle activation anteriorly results in both initial hyperextension and subsequent hyperflexion of the lumbar spine, contributing to large compressive forces during sit-ups.[17,18]

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Traditional sit-ups impose 3300 N of compression on the spine.[14] The National Institute of Occupational Safety and Health has set the action limit of low back compression at 3300 N because repetition loading above this level is linked with higher injury rates; yet this is imposed on the spine with each repetition of a sit-up.[1]

The U.S. military has annual fitness testing where soldiers are required to perform sit-ups. Childs (2010) conducted a wonderful study where two groups of soldiers trained for the sit-up test. One group performed sit-ups; the other group substituted sit-ups with planks. When it came time for the sit-up test, the soldiers who trained with planks performed better on the test than the soldiers who actually trained sit-ups. The soldiers who performed planks had healthier spines, as they avoided the repetitive submaximal microtrauma associated with sit-ups, thus sparing their spines. It is sad and alarming to think of the number of good soldiers who have developed low back injuries, while considering that they were required to perform an exercise that is known to cause injury.

Squats and leg presses are examples of exercises that are not abdominal exercises but can cause low back injuries when performed with poor form. It is not the load necessarily that can cause injury, but the tucking of the pelvis, also known as a posterior pelvic tilt, at the bottom of the squat that flexes the lumbar spine, loading the discs and ligaments. Pelvic tilts flex the spine and preload the annulus and posterior ligaments.[23] While placed under load, this is a powerful mechanism known to cause disc herniations. Note that the load can simply be bodyweight. Stooping to pick something up off the floor can cause disc injury. A fully flexed spine is associated with myoelectric silence in the back extensors, strained posterior passive tissues, and high shear forces on the lumbar spine.[1] Many low back injuries can be prevented by simply avoiding training the spine through its range of motion and avoiding full lumbar flexion.

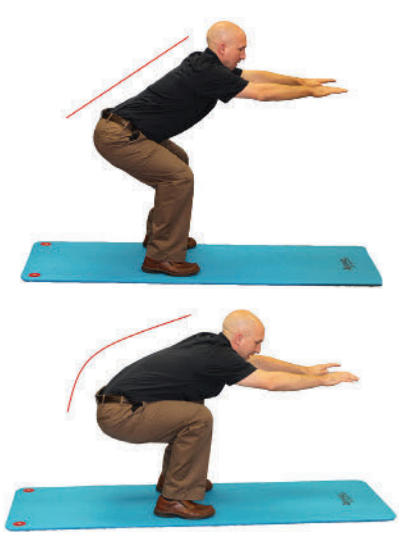

Figure 6. (a) Squat performed with pelvis in the correct position. Red line indicates a neutral spine with normal curvature (b) Squat performed with incorrect form with posterior pelvic tilt. Red line indicates a flexed spine.

My Thoughts

There are safer, more functional, and more challenging ways to train the abdominal wall without introducing injury mechanisms. Do not get caught up in the current trends and fads where you are taught to round, curve, flatten and roll your spine to train your abdominals. I have treated too many low back pain patients who follow current trends (based on a philosophy and not science) that have led to their current dysfunction. Interestingly enough, a spinal fusion for a patient who has a significant disc injury is designed to fuse the vertebrae and stop motion from occurring. Train function, not muscle. A modified curl-up (where the low back is not allowed to flatten), planks, and "stir the pot" are excellent exercises designed to challenge the abdominal wall with little spine penalty, as the spine is spared by being trained functionally in a neutral position. With only a certain number of flexion cycles before discs begin to deteriorate, save them for the important things, e.g., putting on your shoes or petting a dog. Don't train to the test. See the study by Childs mentioned above: those who trained planks did better on the sit-up test than those who trained sit-ups.

> **"Train function, not muscle."**

Too much spine flexibility will cause low back injury. Science has proven this. In symptomatic and asymptomatic workers, the differences between the two groups were things other than spine flexibility and low back strength. Although beyond the scope of this article, the differences between the two groups were faulty movement patterns, aberrant motor patterns, and core muscular endurance (not strength). Again interestingly enough, by correcting faulty movement/motor patterns, training core endurance, and training the spine in the neutral position, pain-free spine range of motion usually returns. Again, don't train to the test!

Spine Extension

As the spine extends (or bends backwards) the facet joints are loaded, and the interspinous ligament is compressed; both at risk for injury. Perhaps the biggest issue with spine extension is the bending of the neural arch loading the pars interarticularis. The neural arch is slightly flexible and analogous to a paper clip. It will bend back and forth several times before it breaks, but it will break. Not surprisingly, repetitive spine flexion/extension cycles causing bending of the neural arch will result in fatigue fractures, leading to spondylolisthesis- a fracture of the pars interarticularis where one vertebra actually slides forward on another due to the loss of anterior shear support.[20,21]

Implications of Spine Extension on Exercise

Exercise 1: "Supermans" result in over 6000 N of compression on a hyperextended spine, crushing the facets and interspinous ligaments.
Exercise 2: Seated back extension machine and "Roman Chair" exercises both cause excessive compression with repeated flexion/extension, leading to fatigue fracture of the neural arch. The excessive compression is known to affect the vertebral bodies and the cartilaginous end plate.
Exercise 3: Hip extension machines cause high shear forces as the hip and low back extend.

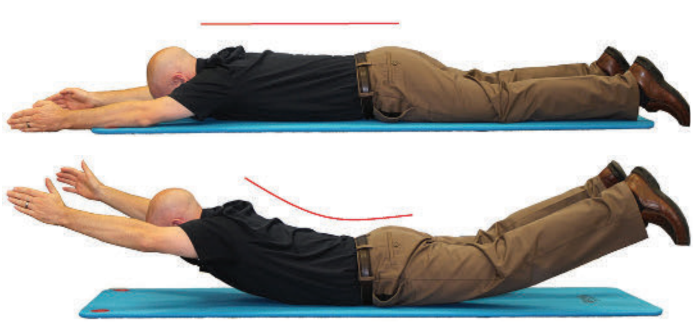

Figure 7. (top) Starting pose for "Superman" exercise. Red line indicates with neutral spine with normal curvature. (bottom) "Superman" exercise. Red line indicates extension of the spine causing compression of the posterior elements of the spine.

My Thoughts

The extensor muscles are designed for muscular endurance as they contain more slow-twitch fibers than fast-twitch fibers. Therefore, training these muscles for strength is ill-advised. Research has shown that all extensor muscles are important, not just the tiny multifidus. In fact, the thoracic extensors are the most efficient lumbar extensors due to their interesting architecture as they course over the lumbar spine, giving them the longest moment arm with least compression penalty. These muscles are designed to maintain an upright posture but create enormous amounts of compression on the spine in hyperextension. The "bird-dog" exercise and all its variations is an excellent exercise to train the extensor muscles while maintaining a neutral spine. The spine pays too high of a price when performing the popular exercises mentioned in the previous section.

Spine Rotation

Rotation or twisting of the spine affects the discs and facet joints. Twisting causes the concentric rings of the annulus to slowly separate, or delaminate, allowing circumferential openings for nuclear material to traverse through.[4] The load bearing ability of the disc is substantially reduced with twisting, as half of the fibers become disabled due to their oblique orientation. Yet with rotation, there is an increase in lumbar muscle co-activation resulting in greater spinal compression on the discs that are already weakened in their twisted state. Additionally, rotation of the spine can cause facet compression allowing the rims of the facets to bind and lock.[22]

Implications of Spine Rotation on Exercise

All twisting or rotational exercises must be considered with caution, as these types of exercises will create high compressive forces on a disc that has lost half of its ability to bear load.

Exercise 4: Seated rotation machines create high compressive forces.
Exercise 5: Russian twists combine with a flexed spine produces a powerful injury and causes discogenic pathology.

Exercise 6: The "Washing Machine" creates high compressive forces.
Exercise 7: Lunges with twists, especially with weights, create high compressive forces.

Figure 8. (a) "Russian twist" exercises starts with a neutral spine facing forward. (b) "Russian twist" exercise rotating to either side and increases the risk of injury since the spine is weakened by the rotation.

My Thoughts

Popular belief is that in order to train the obliques we have to twist. I don't know what this notion is based upon, but it's not science. Too often, twisting is combined with flexion (Russian twist). I call this deadly combination the herniation-maker. The obliques are supremely trained with side bridges and side planks. There are many variations of the side plank to train the obliques and preserve the spine. The obliques can also be challenged with twisting torque, not to be confused with twisting movement. All exercises mentioned above create twisting movement. Twisting torque maintains a neutral spine while challenging the obliques and other core musculature in a functional manner. A rotating plank (rotating through the hips, not the spine) is an excellent choice for training functional rotation.

Traditional exercises, current fads, and popular trends thought to strengthen the spine and prevent low back injury are actually doing just the opposite; they are creating bad backs! The best exercise programs, whether for rehabilitation, general fitness, or performance enhancement, should focus on training the appropriate muscle groups during functional movements while avoiding injury mechanisms.

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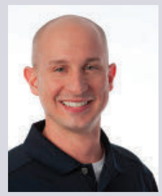

Jason W. Arnett, M.S., A.T.C., P.E.S.

Jason Arnett is a certified athletic trainer at the Virginia Therapy and Fitness Center. His approach with each patient is to develop an individualized comprehensive rehabilitation program that meets the patient's goals while maximizing potential and reducing risk of injury. Jason incorporates a combination of flexibility, balance, core training, and integrated multiplanar resistance training for his patients. Additionally, Jason's research interests include balance and postural stability and psychology of the injured athlete.

Back to the Future: Anterior Cervical Fusion

Justin W. Miller, M.D. and Rick C. Sasso, M.D.

Anterior cervical arthrodesis (fusion) is one of the most common treatment modalities used by spine surgeons when addressing cervical pathology. Arthrodesis is almost always combined with decompression of the neurologic elements in some capacity, whether via a discectomy or corpectomy. Techniques for cervical decompression have not changed tremendously throughout time; however, there have been numerous changes and advancements in fusion techniques.

Anterior cervical discectomy and fusion (ACDF) was first described in the literature by Robinson and Smith in 1955.[1] A discectomy was performed without removal of any uncovertebral spurs or the posterior longitudinal ligament. The end plates were prepared by making several punctures to allow vascularity to access the bone graft. A horseshoe-shaped tricortical iliac crest graft was then inserted into the disc space with a snug fit to provide distraction. This distraction was used to indirectly decompress the neural foramen, removing pressure from the nerve roots. The patient was then placed in a hard cervical orthoses for three months following the procedure.

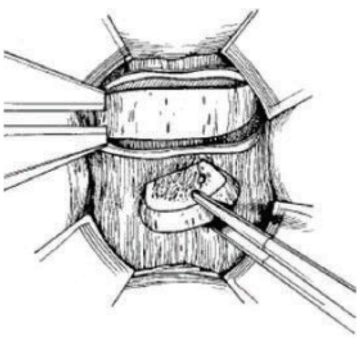

Figure 1. Anterior view of placement of a Smith-Robinson tricortical graft in the prepared disc space in the cervical spine. *Image source:* Albert TJ, Murrell SE: Surgical management of cervical radiculopathy. JAAOS 1999;7:368–376.

Cloward popularized a technique that he first described in 1957 in which an instrument was used to drill a round hole into the intervertebral space and subsequently insert a pre-fit cylindrical dowel of bone.[2] This was a technique that was originally described by Wiltberger for interbody fusion in the lumbar spine.[3] The original instruments were modified by Wiltberger to allow Cloward to work in the cervical region. Cloward obtained the bone dowel from either the patient's own ilium or a bone bank which utilized fresh frozen cadaver specimens. A special dowel-cutting instrument was used to harvest the graft. The dowel was wedge-shaped and 1 mm oversized in diameter to provide a secure fit. Cloward used a cervical collar in his earliest cases; however, he discontinued use of any collar shortly thereafter as he felt motion, specifically flexion of the head, was beneficial in providing compression and impaction of the graft.

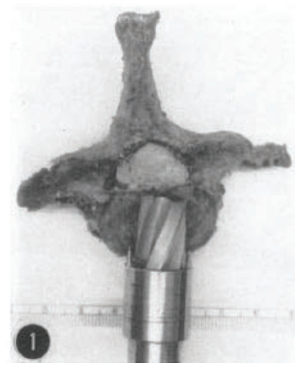

Figure 2. Drill used by Cloward in the intervertebral space. *Image source:* Cloward RB: The anterior approach for removal of ruptured cervical disks. *J Neurosurg* 1958;15:602–617.

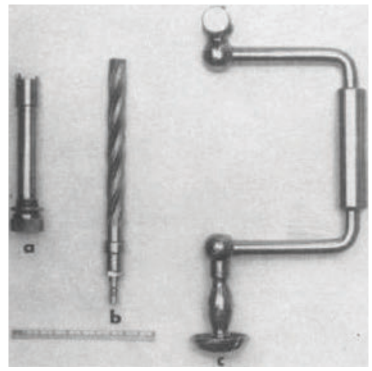

Figure 3. Dowel-cutting instruments used to harvest graft. *Image source:* Cloward RB: The anterior approach for removal of ruptured cervical disks. *J Neurosurg* 1958;15:602–617.

Bailey and Badgley published a technique in 1960 in which a trough was fashioned across the disc space within the anterior aspect of the vertebral bodies.[4] A discectomy was performed, and morselized bone graft was placed within the disc space. An iliac crest strut graft was then harvested and inserted into the trough that had been created. This technique was described for treatment of cervical trauma and fractures. Patients remained in traction for an extended period of time and subsequent brace immobilization thereafter.

In 1969, Simmons described a keystone graft technique in which a wedge-shaped section of bone was removed across the disc space with the use of special osteotomes.[5] With the help of the anesthetist, distraction was applied across the disc space via longitudinal

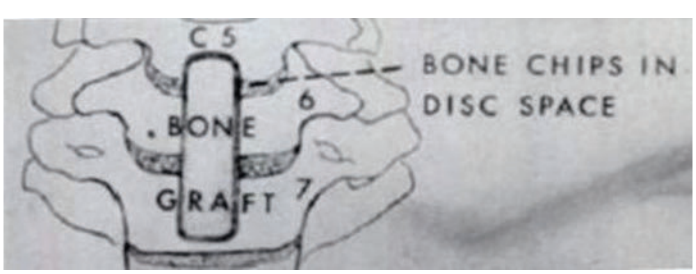

Figure 4. Depiction of trough created within the anterior aspect of vertebral bodies to receive iliac crest graft strut. *Image source:* Bailey RW, Badgley CE: Stabilization of the cervical spine by anterior fusion. *J Bone Joint Surg Am* 1960;42A:565–624.

traction, and the fashioned keystone-shaped graft that had been harvested from the iliac crest was then inserted into place. Due to the shape of the graft, inherent stability was present immediately.

Figure 5. Depiction of Simmon's technique of inserting a keystone-shaped graft in the intervertebral space. *Image source:* Simmons EH, Bhalla SK: Anterior cervical discectomy and fusion: A clinical and biomechanical study with eight year follow-up. *J Bone Joint Surg Br* 1969;51:225–237.

Following the publication of these various techniques in the early 1950's and 1960's, anterior cervical fusion with decompression became more widespread and ultimately standard of care. Modifications in preparation of the disc space and decompression of the neurologic elements occurred over time as surgeons became more familiar and experienced with the surgical approach and technique.

Today, the anatomic approach to the anterior cervical spine is still performed in the exact same fashion as Smith and Robinson described in the 1950's. Preparation of the disc space is performed with a combination of sharp curettes, pituitary rongeur, burring, and decompression with a Kerrison punch. Several advancements have occurred with regard to stabilization of the cervical spine as well as graft options.

Anterior cervical plate fixation has been reported in the literature as early as the 1960's,[6] though common use did not occur until later. By the 1980's and 1990's, anterior cervical plate fixation had become more common.[7,8] Today, in the year 2014, it is unlikely to find an anterior cervical fusion done without instrumentation. Plate designs have changed since their inception beginning with modified plating systems for extremity fractures and progressing to the multitude of designs that we have today.

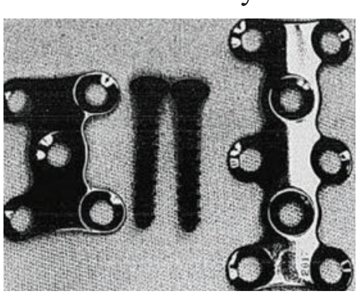

Figure 6. Design of Anterior Cervical Plate Fixation in the 1990's. *Image source:* Aebi M, Zuber K, Marchesi D: Treatment of cervical spine injuries with anterior plating. Indications, techniques, and results. *Spine* 1991;16S:S38–S45.

Figure 7. Examples of current day anterior cervical plates. *Image courtesy of Medtronic, Inc.*

There are three different types of plate designs commonly used today including constrained, semi-constrained, and dynamic. Constrained plates are designed to rigidly fix the screw to the plate, preventing any motion and/or settling of the overall construct. Semi-constrained plates allow for a certain degree of screw toggling, permitting the construct to settle to a degree. Dynamic plating systems allow for maximal compression and load sharing via screw toggling, slotted screw holes, and/or plate translation. Plate designs that are used today also incorporate some form of locking design to resist screw

Figure 8. Constrained plate design. *Image courtesy of Medtronic, Inc.*

Figure 9. Semi-constrained plate design. *Image courtesy of Medtronic, Inc.*

Figure 10. Dynamic plate design. *Images courtesy of Medtronic, Inc.*

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back out. This is typically done with an integrated mechanism including cam or memory deflection in nature.

Graft options historically were limited to harvesting of iliac crest or fibular strut grafts. Today there are numerous options including autograft, allograft, or synthetic grafts. Due to the morbidity associated with harvesting autograft, the majority of anterior cervical fusion procedures today are performed with allograft bone or synthetic materials. Allograft bone typically is in the form of cortical or cortico-cancellous fibula. Synthetic options include metallic implants and polyethyl ethyl ketone (PEEK). Fusion rates for single level fusion with allograft and plate fixation are comparable to fusion rates with autograft.

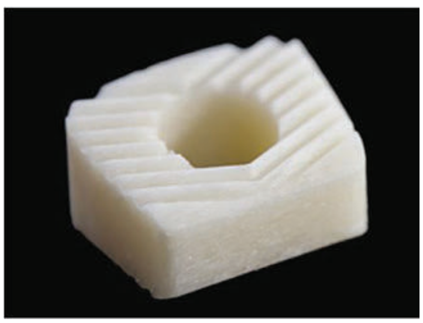

Figure 11. Allograft Bone. *Image courtesy of Bone Bank Allografts.*

Figure 12. Synthetic PEEK Implants. *Image courtesy of Medtronic, Inc.*

Anterior cervical arthrodesis is one of the most common procedures that we as spine surgeons perform. It is a very successful procedure and provides significant improvement in quality of life and return to normal pain-free function. Although certain aspects of the procedure remain similar to the original descriptions, technology has allowed us to advance. These advancements are designed to promote better fusions and have allowed for easier recovery. We as surgeons and researchers are always searching for innovative ways to improve upon our current treatment methods.

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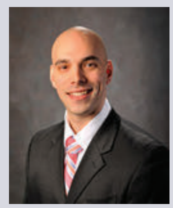

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Dr. Miller is a fellowship-trained orthopedic spine surgeon with Indiana Spine Group. His special medical interests include taking care of many spinal disorders, including disc herniations, arthritic/degenerative processes, spinal stenosis, complex pediatric and adult kyphotic and scoliotic deformities, sports-related injuries, spondylolisthesis, myelopathy, infections, trauma, oncology, and revision surgeries. Dr. Miller also specializes in minimally invasive spine surgery and cutting-edge spinal stealth navigation techniques. He has undergone extensive training in his field due to the complexity of spinal and neurologic disorders with a goal of providing the highest level of care to his patients. Dr. Miller is also interested in advancing his specialty and is co-investigator on a number of current studies with the Indiana Spine Group. His research interests include degenerative disc disease, infection prevention, lumbar stenosis, and osteoporosis, to mention a few.

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Transformation of Spinal Deformity Treatment

Christopher R. Good, M.D., F.A.C.S. and Blair K. Simonetti, P.A.-C.

Abstract

Treatment of spinal conditions dates back to ancient times. There has been a long history of treatment of scoliosis and other spinal deformities using both non-operative and operative techniques. One of the most common techniques used by spine surgeons to correct spinal problems is spine fusion. The purpose of a spinal fusion is to create a rigid union between two separate segments of the spine to correct malalignment or instability. Many different types of spinal instrumentation have been developed to help facilitate spine fusion, including devices such as rods, plates, hooks, wires, and screws.

Treatment of spinal deformity has improved due the development of enhanced spine imaging, advanced surgical techniques, and improved spinal instrumentation. These advances allow surgeons to help their patients maximize their quality of life while striving to minimize the potential for complications. Advances in the past few decades have improved correction of spinal deformity and decreased the morbidity of surgical procedures, while allowing for earlier return to activity after surgery. Current research focuses on improving and developing motion preserving surgical techniques and safer, less invasive surgical options.

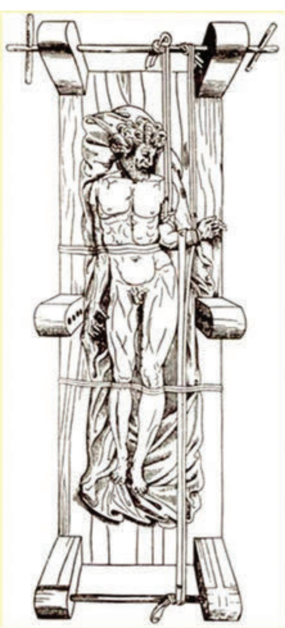

Figure 1. The Hippocratic board was used to place corrective forces on the spine using bands and straps to correct spinal deformities. *Image source:* the illustrated comments of Apollonius of Kitium on the Hippocratic treatise *On Articulations.* Bibliotheca Medica Laurenziana, Florence.

History of Spinal Deformity

There are records of spinal treatments dated back to thousands of years ago. Fractures of the bones of the neck causing paralysis have been documented as early as 1550 B.C. in ancient Egyptian writings. At that time, patients were treated by priests who applied bandages and helped patients to rest. Hippocrates (460–337 B.C.) was an ancient Greek physician who is considered to be the father of western medicine. Hippocrates worked to develop methods for treating fractures of the spine by positioning patients in such a way as to correct a deformity that developed after a spinal fracture. Using his techniques, therapists used wooden constructs to place forces against the patient's spine in order to correct or reposition fractures.[1] A number of physicians built off of Hippocrates' early work to develop more advanced techniques for treating fractures with a variety of traction or spinal manipulation devices. These included techniques such as hanging patients on a ladder or placing patients on a table with ropes attached around the torso and ankles.

> **"Scoliosis is an abnormal curvature of the spine that affects 1 to 3% of the general population, or approximately seven million people in the United States."**

Scoliosis, another condition which causes deformity, is derived from a Greek word meaning a lateral curvature of the spine. The word scoliosis was coined by Galen of Pergamon (129 to 200 A.D.). Scoliosis is an abnormal curvature of the spine that affects 1 to 3% of the general population of the United States, or approximately seven million people. Bracing is used to prevent and/or limit progression of scoliosis curves during

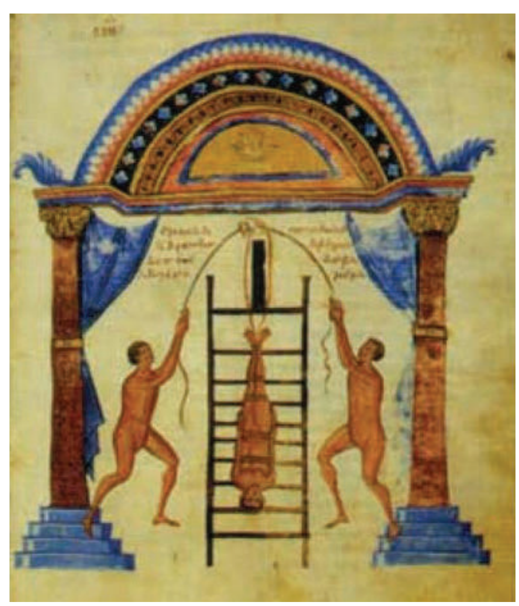

Figure 2. The Hippocratic ladder was used for the correction of spinal deformities with the head pointing downwards. *Image source:* the illustrated comments of Apollonius of Kitium on the Hippocratic treatise *On Articulations.* Bibliotheca Medica Laurenziana, Florence.

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periods of maximal patient growth for moderate curves (generally between 25° to 45°). Surgical treatment is considered for patients with curves greater than 40° to 50°. There has been a documented risk for continued curve progression from 0.5° to 2° per year for curves greater than 50° in adults.

Patients with spinal deformities may have complaints related to cosmesis including difficulties with rib hump, shoulder height, pelvic obliquity, or truncal shift. If curves are left untreated, more severe conditions may develop. Pulmonary function has been shown to decrease as curves increase in size. Pulmonary function becomes significantly limited as thoracic scoliosis becomes more severe, particularly for curves that are greater than 80°.[2,3]

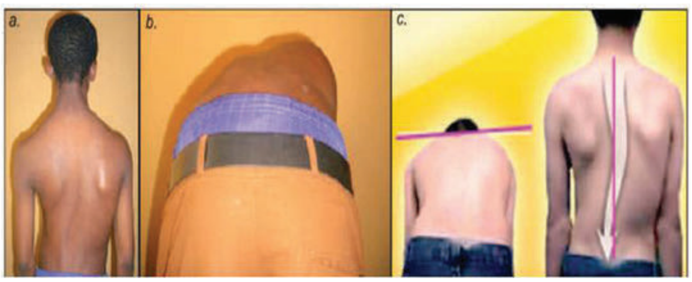

Figure 3. Patients with spinal deformities may notice changes in their alignment including rib hump, shoulder height, pelvic obliquity, or truncal shift. *Image courtesy of Medtronic, Inc.*

Evolution of Spine Surgery

Operative intervention for spinal conditions was initially slow to develop because of difficulties with infections. This situation changed beginning in 1867 when antisepsis became a standard practice, which increased safety of operative procedures. Surgical intervention was also greatly advanced with the development of local anesthesia and general anesthesia.[1] The benefits of surgical intervention include the ability to release pressure on neurologic elements as well as stabilization of the spine to allow for early patient mobilization. Decreasing the length of bed rest has been influential in minimizing further complications that can result from prolonged inactivity including pneumonia, blood clot, pulmonary embolism, and pressure sores.

The first laminectomy was performed in the United States in 1829 when Dr. Alban Gilpin Smith removed a fractured spine bone to treat a patient with progressive leg weakness. This patient reportedly recovered well and improved neurologically. Later in 1888, Dr. Smith successfully removed a spinal tumor that was causing neurologic compression and was able to perform more involved surgeries to correct vertebral bones damaged by tuberculosis infections.[4] Because tuberculosis was so common in the United States at the time, most spinal surgeries were performed for this reason. However, as time progressed, surgery also began to be used for other conditions including spinal deformities, fractures, and tumors.

History of Spine Fusion

The purpose of a spinal fusion is to create a rigid union between two separate segments of the spine to correct segmental malalignment or instability. This is similar to trying to get two edges of a broken bone to heal together after a fracture. Fusion does eliminate motion at that segment; however, this may be appropriate for patients with instability or deformity.

Spinal fusion was initially performed by placing bone graft along the bones of the spine and fusing the spine "in situ." That is, fusing the spine in its current position without an attempt of correcting spinal alignment. The earliest fusion procedures were performed without the use of instrumentation. In order to support the spine and avoid motion while the fusion was healing, patients were placed in casts, traction, or braces after their surgeries. This technique required prolonged periods of bed rest and immobility ranging from six months to one year while patients were in casts or traction and ultimately led to very high rates pseudarthrosis (an area of the fusion that did not heal). Russell Hibbs performed the first spinal fusion for scoliosis in 1914. The pseudoarthrosis rate of initial spinal fusion surgeries performed by Dr. Hibbs was approximately 60%. Starting in the 1940s, there was a period of approximately twenty to thirty years when posterior fusion and cast immobilization were the standard of care. As fusion techniques improved, pseudoarthrosis rates were typically around 45%.

Spine fusion was also used during this time to treat fractures of the spine. Spine trauma can result in instability as a result of a fracture to the bone or an injury to the ligaments that support the bones of the spine. Many fractures can be treated conservatively with bracing or casting; however, with specific instability patterns, surgical intervention has been recommended.

Spinal Instrumentation

Surgery for scoliosis was the first widespread application of spinal instrumentation. Over the years, many different types of techniques and instrumentation have been developed to help correct spinal curvatures and facilitate fusion. Specific instrumentation types include: metal plates, rods, hooks, wires, and screws which join together to support the spine during the time that it is fusing. The use of metallic implants to stabilize segments allows for faster and more effective fusion. The early instrumentation systems functioned to act as an "internal splint" which held the spine in position until the surgically applied bone graft developed into a fusion mass.

"Surgery for scoliosis was the first widespread application of spinal instrumentation."

There are many goals that are achieved by spinal instrumentation. For patients with spinal deformities, implants should maintain correction of the deformity after surgery until spinal fusion can occur. Solid immobilization with spinal instrumentation enhances the rates of bony fusion. For patients with instability or fractures, spinal instrumentation allows for stabilization of this instability and facilitates early mobilization to help avoid potential side effects of prolonged bed rest. In recent years, the number and types of spinal implants available has greatly increased. To best understand the use of instrumentation, one must fully understand the spinal disorder that is to be treated and the specific goals of treatment.

The evolution of modern spinal instrumentation systems began in the late 1950s with the development of the Harrington hook and rod system. At this time, this was a major medical breakthrough that allowed for enhanced stability and curve correction for patients with spinal deformity. The Harrington rod and hook system consisted of a rod with a hook at either end. These hooks attached to the spine at the top and the bottom of the curvature. By distracting across the rod, surgeons were able to partially reduce spinal deformities. This technique was most commonly used to treat paralytic scoliosis resulting from poliomyelitis which was very common at that time. This system was limited in that it only attached to the spine in two locations. Additionally, this did not allow surgeons to accurately re-create a normal spinal alignment, particularly in the sagittal plane (viewed from the side) because the rod was straight and not curved as the spine is naturally.

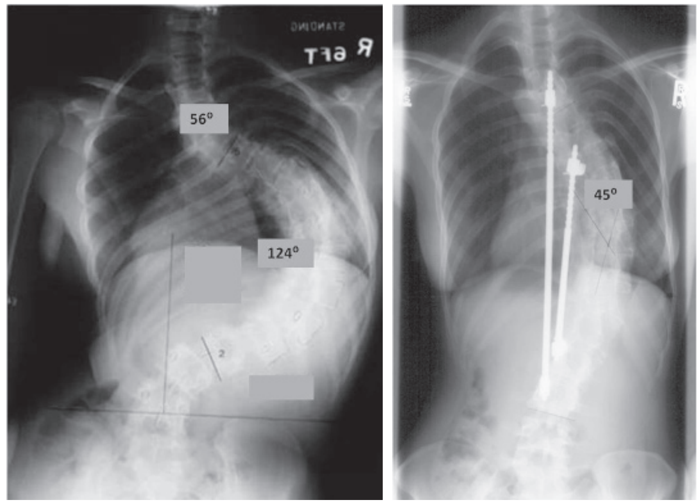

Figure 4. The Harrington instrumentation system consisted of a rod with a hook at either end. These hooks attached to the spine at the top and the bottom of the curvature. By distracting across the rod, surgeons were able to partially reduce spinal deformities. *Case courtesy of Keith H. Bridwell, MD.*

Harrington distraction instrumentation did address the frontal (S-shaped) curve of the scoliosis pattern; however, the sagittal contour of the patient was often negatively influenced, particularly the lumbar spine. The distraction forces of the Harrington instrumentation tended to decrease the amount of lumbar lordosis (swayback) which led some patients to develop a "flat-back syndrome." These patients developed low back pain and a loss of normal standing alignment when viewed from the side.[5,6]

Segmental instrumentation was first introduced by Edwardo Luque of Mexico in 1973. He used a two-rod system in the back of the spine which was attached to the spinal bones with wires at each level of spine. These rods were contoured in multiple planes which did allow for surgeons to fuse the spine in a more normal alignment. By attaching the implants to the spine at multiple levels, the force exerted on individual level was reduced, and the overall potential for spinal correction was increased. By using these powerful techniques, Dr. Luque was able to treat many of his patients without the use of long-term casting or bracing after surgery.

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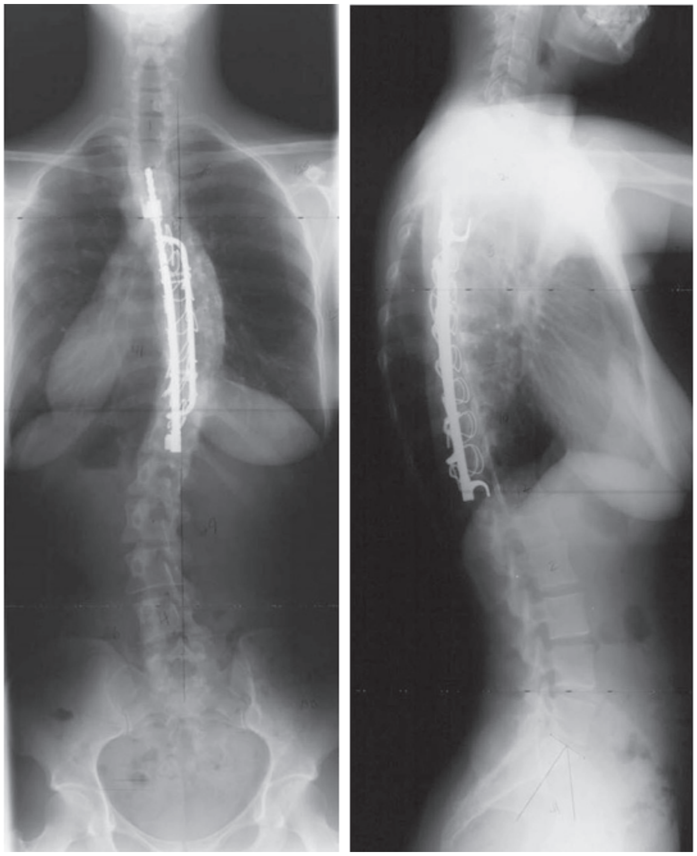

Figure 5. Segmental instrumentation as introduced by Edwardo Luque. This two-rod system was attached to the spinal bones with wires at each level of spine. These rods were contoured in multiple planes which allowed for surgeons to fuse the spine in a more normal alignment. *Case courtesy of Keith H. Bridwell, MD.*

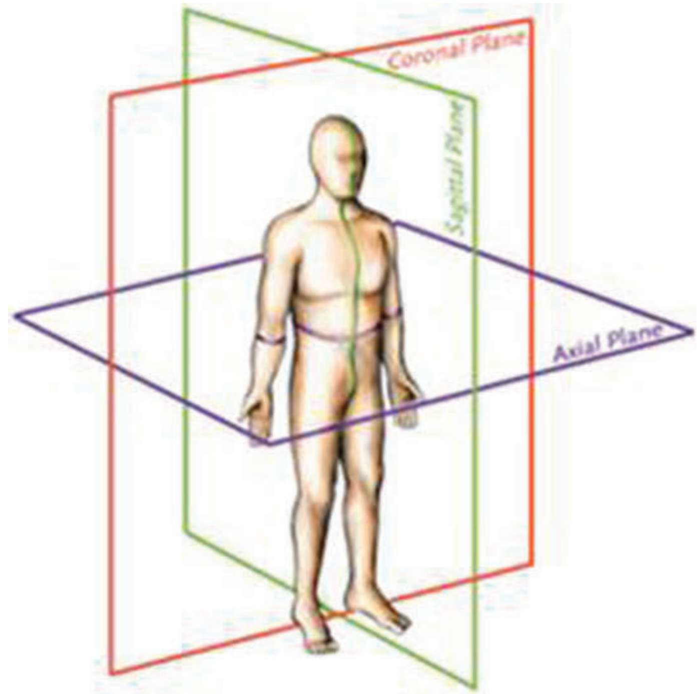

Figure 6. Anatomical planes. The coronal plane is a view of the patient from the front; that is the view that shows the "S-shape curve" of scoliosis. The sagittal plane is a view of the patient from the side. The axial plane is a cross-sectional view that describes the rotation of the spine bones in scoliosis. *Image courtesy of Medtronic, Inc.*

Dr. Luque reported on a series of 322 patients treated with his techniques in 1982. Failure of the instrumentation occurred in 27 of these patients and 5% of the patients developed a pseudoarthrosis. This was a particularly low rate at that time, especially considering that the majority of Dr. Luque's patients were treated for neuromuscular conditions including poliomyelitis and cerebral palsy and were therefore at a high risk for postoperative problems.[7]

Segmental fixation with wires did improve correction of the frontal plane and allowed for the maintenance of a physiologic sagittal contour; however, spinal deformities occur in three dimensions, and none of these early techniques allowed for rotational correction during surgery. In the 1980s, a new treatment system was introduced using the Cotrell-Dubousset instrumentation system (CD). The CD instrumentation system allowed for multiple fixation points along the spine using a variety of hook and rod combinations. This instrumentation system allowed for correction of the spine in the coronal, sagittal, and axial (rotational) planes during spinal reconstructions, which was a major technical advancement.

In Dr. Cotrell's original report of 250 patients, no patient was treated with postoperative bracing or casting. The average correction of scoliosis was 66%, and sagittal contour was also improved. Less than 5% loss of the correction was noted over long-term follow-up. No failures of the instrumentation were noted.[8]

Another advancement in spinal instrumentation was the development of crosslinking devices. Cross-links are simple transverse implants that connect between rods that are placed on each side of the spine. These devices provide additional stability to spinal instrumentation. The TSRH implant system was the first to utilize cross-links and was developed at the Texas Scottish Right Hospital in 1983. This system also made extension of a previously implanted system to another system possible.[9]

Figure 7. Crosslinks are transverse implants that connect between rods that are placed on each side of the spine to provide additional stability to spinal instrumentation. *Image courtesy of Medtronic, Inc.*

Recent Surgical Advances

Surgical techniques have developed to be able to access and attach to the spine and correct deformities from the front (anterior) as well as the back (posterior) side of the spine. The early benefit of surgeries performed through the front of the spine was that they allowed direct access to the bones and discs in the front of the spine and offered the benefit that fewer total levels of the spine needed to be fused in cases of scoliosis. As techniques improved for surgery on the front of the spine, implants were also developed to help fill bone defects resulting from infections or tumors. A variety of titanium cages, bone grafts, and other devices have been developed for this purpose.

Advancements in spinal technologies and spinal surgery technologies continued in the 1990s. These new systems have developed techniques that allow for the spine to be fixed segmentally, meaning that attachment of metal implants to the rod is achieved at every level that is being addressed. Stronger segmental fixation of the spine has allowed for better correction of spinal deformities, increased rates of bone healing or fusion after surgery, and decreased rates of instrumentation failure. Most recently, a trend has been towards an increased use of pedicle screw instrumentation to allow for spinal fixation. Pedicle screws are placed into a specific anatomic area of the spine from a posterior approach. Surgeons began using pedicles screws in 1988. The initial constructs were pedicle screws in the lower lumbar spine where they were easier to place due to larger bone size, with continued use of hook and wire patterns in the upper end of scoliosis reconstruction.

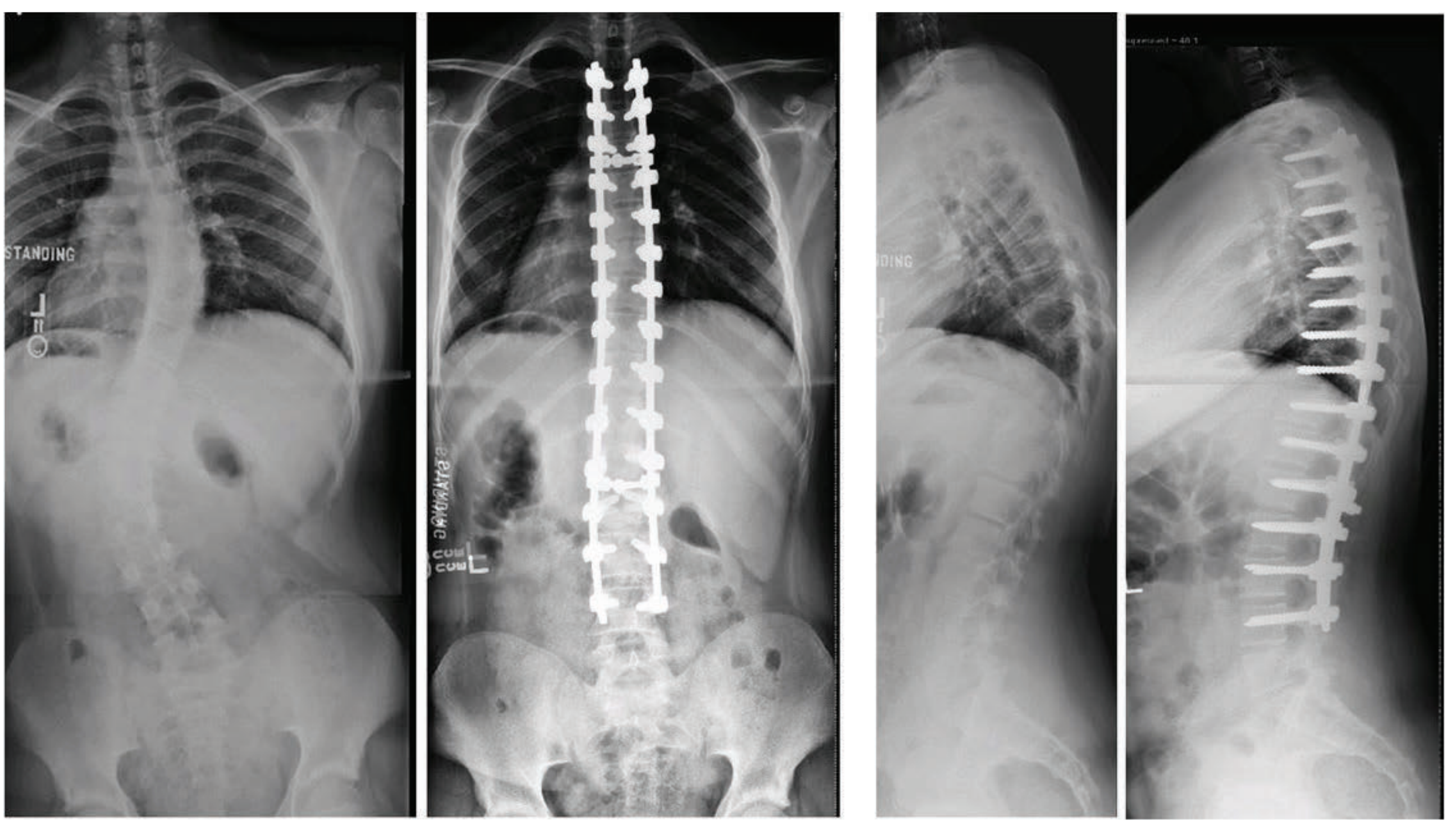

Figure 8. Scoliosis correction using segmental pedicle screw fixation at each level of the spine.

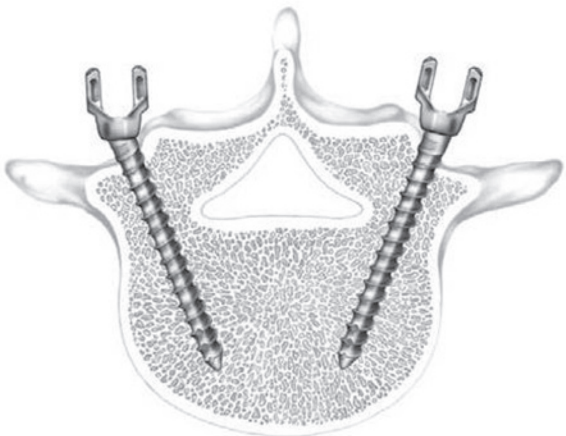

Figure 9. Pedicle screws are placed into the vertebral bone on the side of the spinal canal. *Image courtesy of Medtronic, Inc.*

These rigid segmental fixation systems allow most patients to be mobile immediately after surgery without postoperative immobilization which is a benefit not offered by previous systems. However, there are some disadvantages to the newer instrumentation systems. First, increased correction of spinal deformity can be associated with an increase in neurologic injuries. In addition, the instrumentation systems were more bulky than previous implants and were noted underneath the skin, particularly in very thin patients. Finally, as more implants are utilized for each surgery, the overall cost of each surgery is more expensive.

Pedicle screw fixation is more rigid than previous hook, rod, or wire implants and has therefore allowed for improved correction of spinal curvatures and higher fusion rates. Another benefit of pedicle screw implants is that they require fewer segments to be instrumented and fused during deformity correction. In 1995, Se-II et al. reported an average scoliosis correction of 72% with all pedicle screw constructs, and a loss of correction over time at only 1% versus 6% previously documented with hooks. They also noticed an increased rotational correction at 59% with pedicle screws versus a 19% correction with hook construct.[10]

Kim et al. subsequently evaluated the safety of pedicle screw placement in the thoracic spine over a ten-year period with of 3,204 screws implanted. Screws were analyzed by a computerized tomography (CT) scan, and 6.2% of screws were noted to have some moderate cortical perforation. Of these screws, none were associated with any neurologic, vascular, or visceral complications.[11] Kim et al. also evaluated the average number of levels fused comparing hooks versus screw systems. They noted that the pedicle screws saved an average 0.8 levels per patient when compared with hook constructs.[12]

The use of pedicle screw implants has also allowed surgeons to perform more complex spinal reconstructions including spinal osteotomies. With these procedures, complex and rigid spinal curvatures can be addressed by cutting away portions of the spine bone (osteotomy) that are involved in the deformity, allowing a greater reapproximation of normal coronal and sagittal contours.

Ongoing Research

Current research is also focused on the use of nonfusion techniques, particularly for young patients with spinal deformity. New techniques have been developed that allow for a partial correction of spinal deformity without a fusion until the completion of spinal growth. These techniques have included the use of vertebral stapling, growing rods, and Vertical Expandable Prosthetic Titanium Rib (VEPTR) placement.

Vertebral stapling is a procedure that is used for teenagers with progressive moderate scoliosis. During the procedure, staples are placed on the convexity

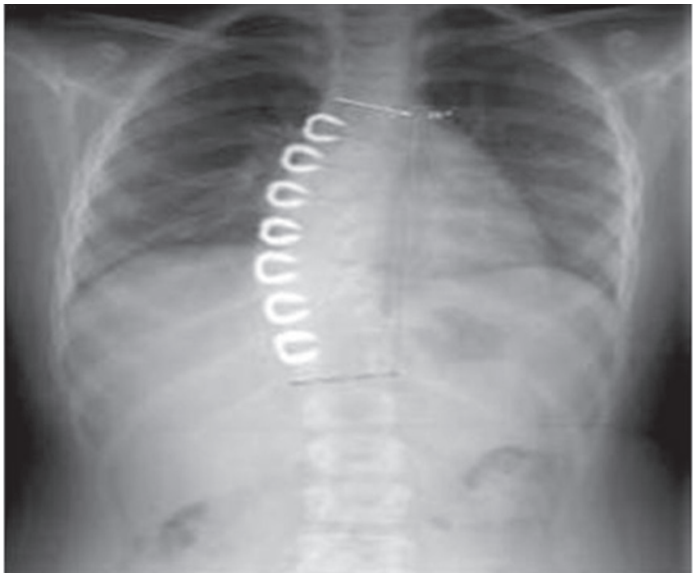

Figure 10. X-ray of a patient who has undergone vertebral stapling for progressive moderate scoliosis. Staples have been placed on the convexity (outside) of the curve without performing a fusion.

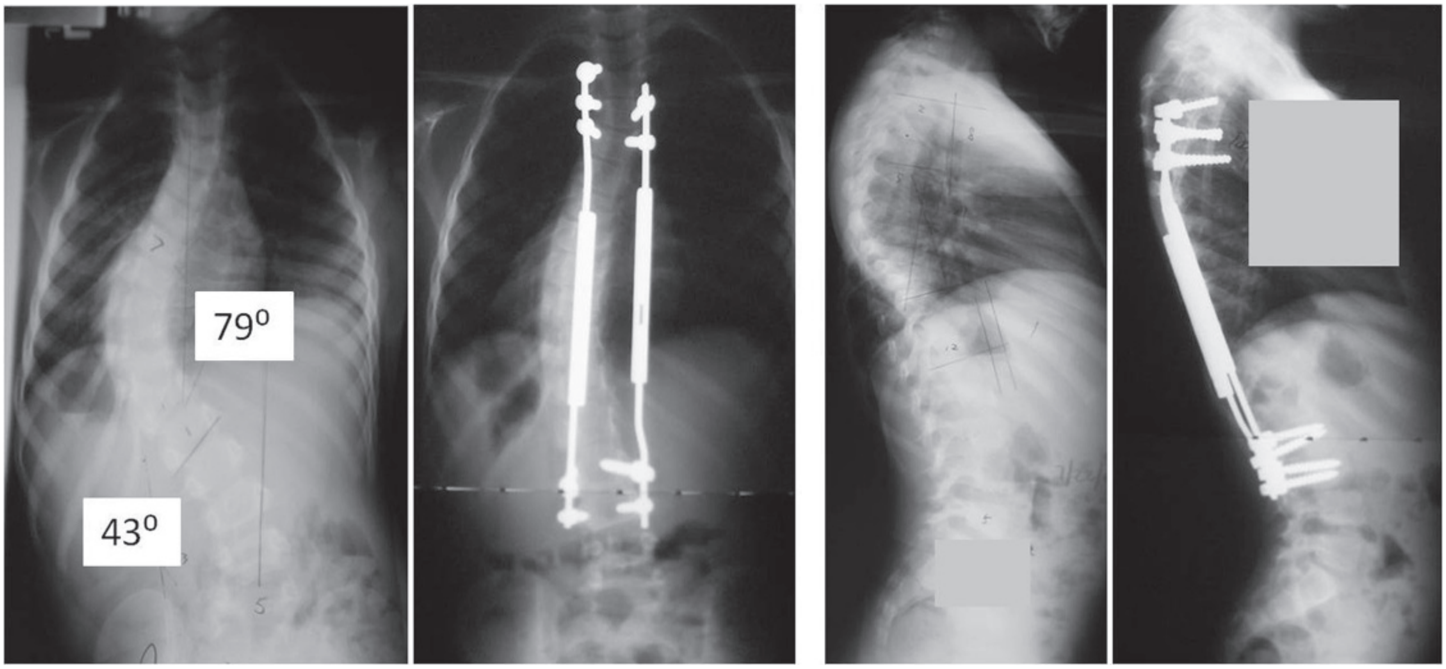

Figure 11. Growing rods are attached to the spine at the top and the bottom of the curvature, but do not fuse the spine in the motion segments in the middle. These rods are periodically lengthened, which allows for continued spinal growth at the non-fused segments. *Case courtesy of Lawrence G. Lenke, MD.*

(outside) of the curve without performing a fusion. These staples tether growth on the "long" side of the spine while allowing further growth on the "short" side. As growth continues, a curvature may be halted or even straightened as the two sides become more equal in length.[13]

Growing rods are also utilized for children with progressive curvatures who have significant growth remaining. They are attached to the spine at the top and the bottom of the curvature, but do not fuse the spine in the motion segments in the middle, allowing for continued spinal growth at the non-fused segments. The rods are periodically lengthened as the child grows which allows for growth of the spine while slowing the progression of a curvature.[14]

Another technique that has been used in children with progressive curvatures is the VEPTR approach. The VEPTR device works to expand and support a deformed chest wall cavity by using telescoping titanium rods. These rods hook to the ribs or pelvis and can help to separate and support the chest. This device may slow the progression of a spinal curvature and avoid a spinal fusion in young children until they have neared the end of their growth.[15]

Robotic Spine Surgery

Robot-guided spinal surgery offers many potential advantages to patients and surgeons including improving the safety of minimally invasive as well as complex surgical procedures, improving the accuracy of spinal instrumentation, and minimizing the use of radiation during surgery. Robot-guided spine surgery utilizes highly accurate, state-of-the-art technology for the treatment of many spinal conditions including degenerative spinal conditions, spine tumors, and spinal deformities.

How It Works

The Mazor Robotics Renaissance™ system is one of the only robotic guidance products in the United States used for implanting devices during spine surgery. The Mazor Robotics system allows the surgeon to use the images from a CT scan that are taken before surgery to create a blueprint for each surgical procedure. The CT scan information is loaded into a computerized 3D planning system which allows the surgeon to plan the surgical procedure with a high degree of precision before ever entering the operating room.

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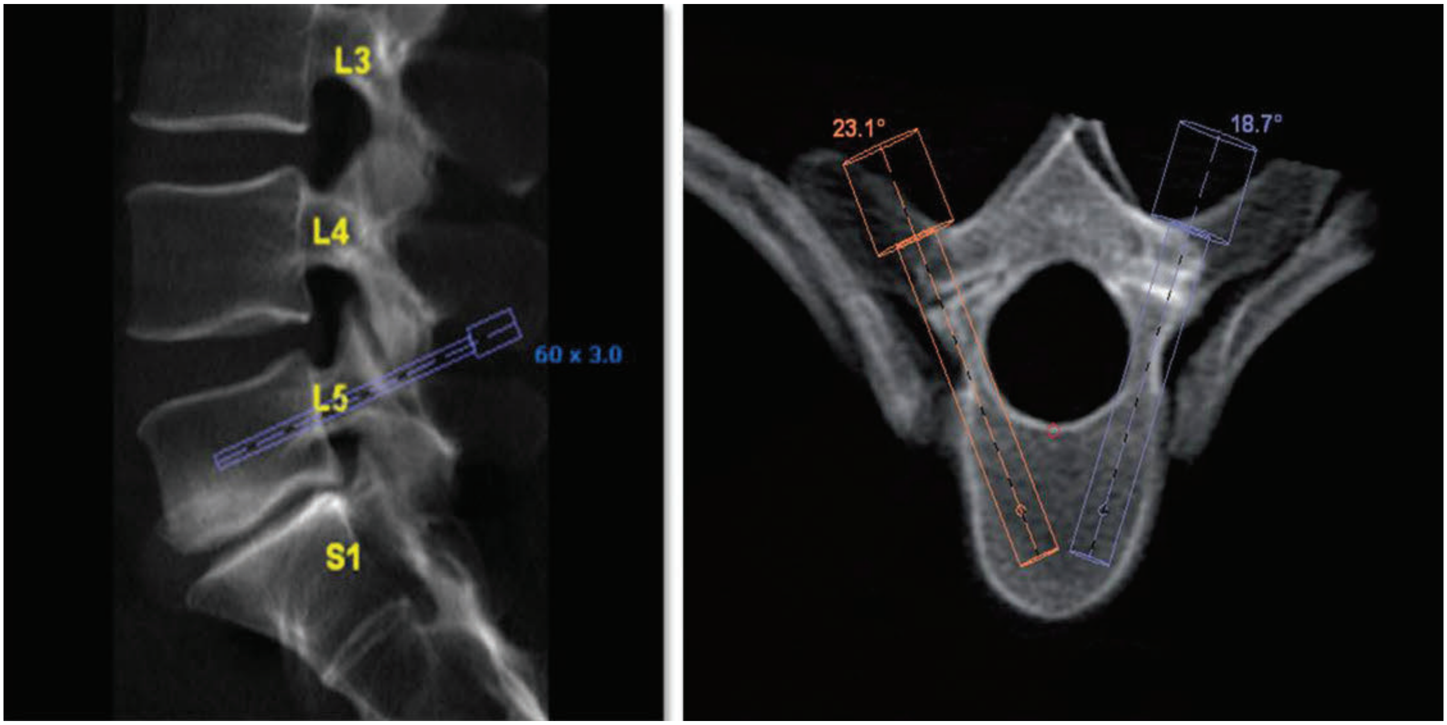

Figure 12. CT scan images of the spine are taken prior to surgery and the exact location of spinal implants is blueprinted with 3D software. The orange and purple lines represent screws that are to be placed into the bones of the spine.

In the operating room, the surgeon does all of the actual work of the surgery. The robot-guidance system is a tool that helps to guide the surgeon's instruments, based on the previous planning, to place spinal implants with a high degree of accuracy. During the surgery, the robot is placed near the patient either by attaching it to the bed or directly to the spine of the patient. The robot is approximately the size of a 12-ounce beverage can with a small arm attached. The robot has the ability to bend and rotate in order to place its arm on the spine in a very specific location and trajectory. This highly accurate guidance can improve the surgeon's ability to safely place implants, particularly when working through very small incisions (minimally invasive surgery) or when dealing with complex anatomy (spinal deformity or previous spine surgery).

Scoliosis Correction Surgery

Surgery for scoliosis involves the use of spinal instrumentation such as screws, rods, hooks, and wires which are placed along the spine. Surgery treats but does not cure scoliosis; it corrects the abnormal curvature and prevents further progression of the disease. Surgical treatment of scoliosis requires a high degree of planning and precision. Each specific curve pattern is

Figure 13. The Mazor Robot is attached to the spine of the patient and the arm is helping to guide the surgeon's hand during a minimally invasive surgery. *Image courtesy Mazor Robotics, Ltd.*

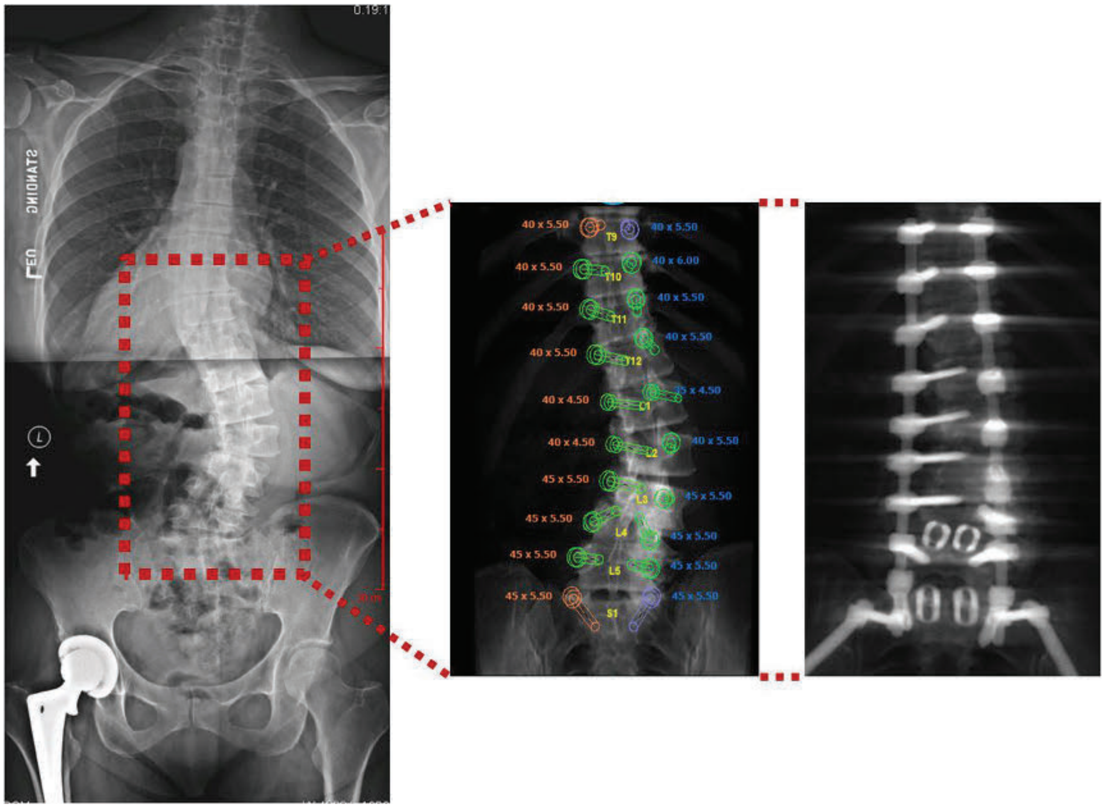

Figure 14. The x-ray on the left shows a patient with thoracolumbar scoliosis. The middle image demonstrates the pre-operative blueprint showing the location where screws will be placed during scoliosis correction surgery. The x-ray on the right shows the final location of the implants after surgical correction.

unique, and many patients with scoliosis have unusually shaped bones of the spine which make surgery more challenging.

Robot-guided scoliosis correction offers increased precision of instrumentation placement and therefore an increase in the safety of the surgical procedure. It offers the surgeon the ability to carefully plan ahead before entering the operating room and design the ideal procedure for each patient. Studies have validated superior clinical results for adolescent scoliosis with robotic technology based on improved accuracy of implant placement and safety. In a recent study of 120 teenagers with scoliosis, robot-guided surgery was found to achieve 99.7% accuracy of 1,815 implants placed.[4]

"In a recent study of 120 teenagers with scoliosis, robot-guided surgery was found to achieve 99.7% accuracy of 1,815 implants placed."

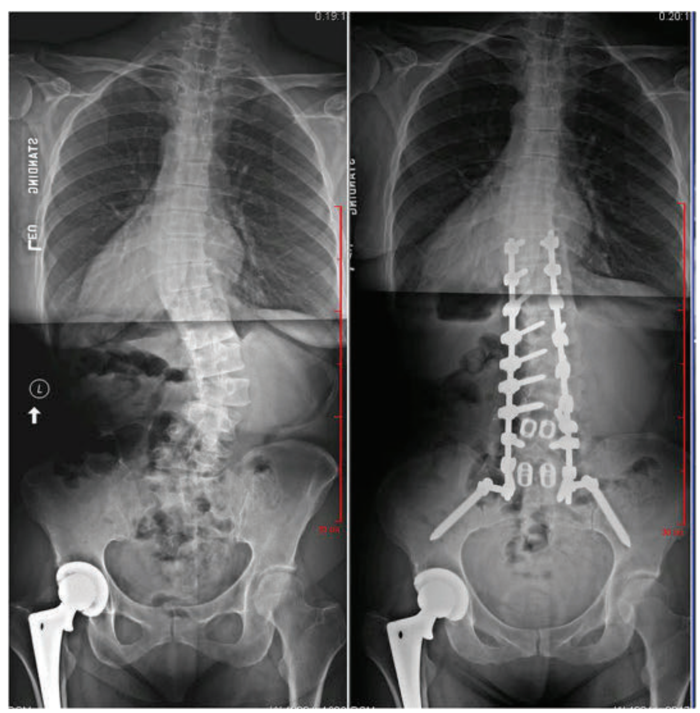

Figure 15. X-rays taken before and after scoliosis correction surgery.

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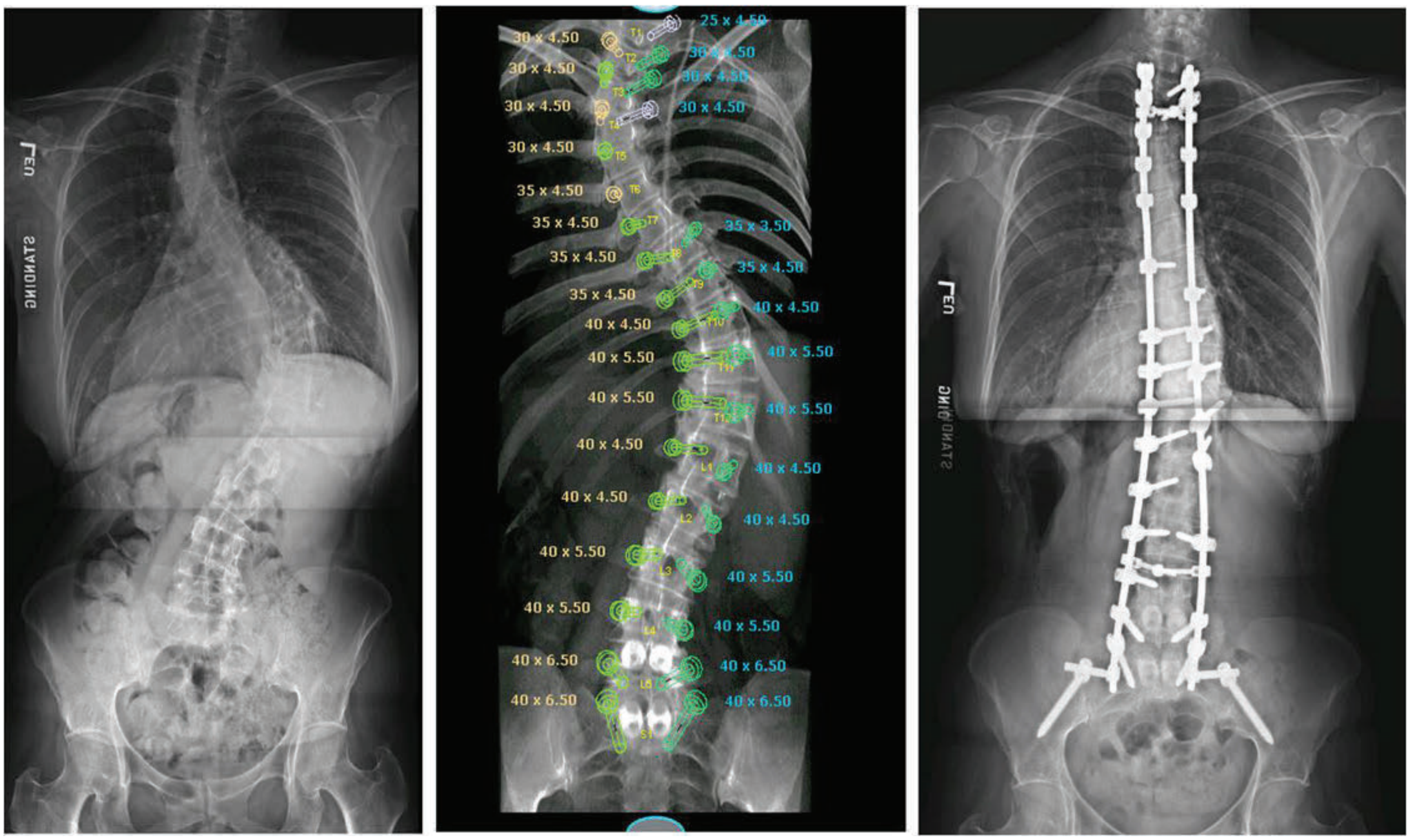

Figure 16. The x-ray on the left shows a patient with large thoracic and lumbar scoliosis which is effecting heart and lung function. . The middle image demonstrates the pre-operative blueprint showing the location where screws will be placed during scoliosis correction surgery. The x-ray on the right shows the final location of the implants after surgical correction.

Robot-guided spine surgery is a promising new technology that has many advantages and may allow surgeons to perform less invasive surgical procedures with smaller incisions, less bleeding, faster recovery, and shorter hospital stays. Robot-guidance can also increase the accuracy and safety of surgical procedures and allow procedures to be performed with less intra-operative radiation exposure to patients and health care providers.

Conclusion

Treatment of spinal deformity has improved due the development of advanced surgical techniques and improved spinal instrumentation. These advances allow surgeons to help their patients maximize their quality of life while striving to minimize the potential for complications. Advances in the past few decades have improved correction of spinal deformity and decreased the morbidity of surgical procedures, while allowing for earlier return to activity after surgery. Current research focuses on improving and developing motion preserving surgical techniques and less invasive surgical options.

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A Brief History of the Evolution of Lumbar Spinal Surgical Decompression

Patrick T. O'Leary, M.D.

Spine surgery has a fascinating history-from initial understanding of spinal anatomy thousands of years ago clear to present developments in the modern day. Some of the earliest depictions of spinal traction to correct spinal deformity date back to almost to 3500 B.C.! Perhaps one of the most interesting historical aspects of spinal surgery, though, is the development of the laminectomy or spinal decompression surgery. The laminectomy is arguably the first spinal surgery performed, and to this day, various permutations of the laminectomy make it the most commonly performed spinal procedure. The lamina is the posterior arch of the spine, sometimes referred to as the roof of the spinal canal. The following will be a brief history of the development and progression in technique of the "cornerstone" procedure for the treatment of spinal pathology.

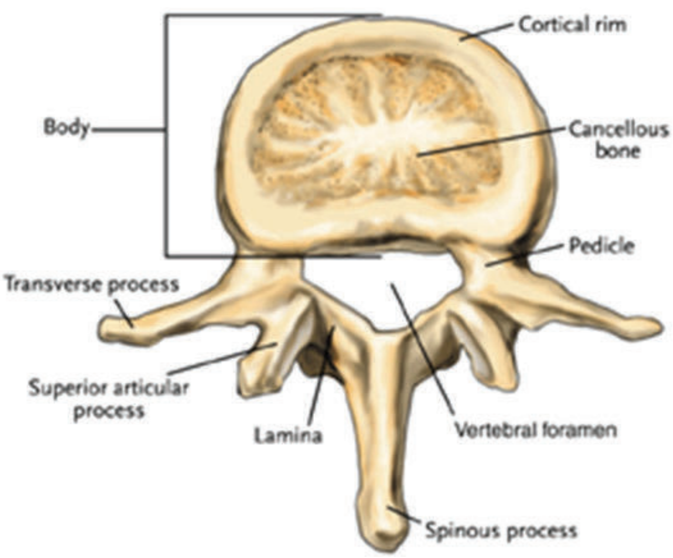

Figure 1. Axial view of a lumbar vertebra. The two laminae are bony plates that form the posterior border of the vertebral foramen and connect with the pedicles to form the vertebral arch. *Image courtesy of Medtronic, Inc.*

The first historical description of spinal laminectomy occurred perhaps as early as 650 A.D. Paulus of Aegina is regarded as the first person to perform what is now known as the laminectomy.[1] It is believed that indication was for spinal cord compression following spinal trauma. However, it was more than a century later, following this first description, before open surgical spinal decompression was described again.

Review of medical history suggests that the laminectomy procedure was advocated for as early as the 16th century, but it was not performed until the early 1800s.[2] The main indications for laminectomy tended to be decompression of the neural elements for bony compression due to trauma, infection, or tumor. Laminectomy was the only surgical spinal procedure for more than a century until deformity correction and other developments took place during the 20th century!

> **"The laminectomy is arguably the first spinal surgery performed, and to this day, various permutations of the laminectomy make it the most commonly performed spinal procedure."**

The early case reports of laminectomy in the 19th century were not all well-received. Like any new technique, a learning curve existed, and complications occurred. Some of the patients undergoing spinal decompression for spinal cord compression likely had significant spinal instability and neurologic compression, and while laminectomy was an attempt to provide more space for the spinal cord and neural elements, the severity of the underlying injury did not allow for significant recovery. Nonetheless, early mortality following these procedures was high, and there was great debate in British medical circles regarding the efficacy of such procedures.[3,4]

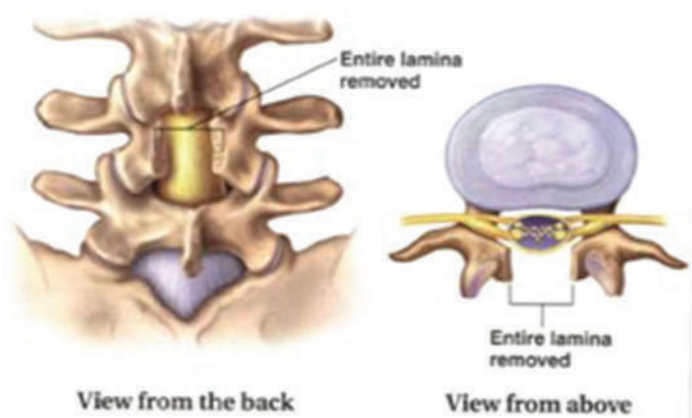

Figure 2. Spinal column (left) and single vertebra (right) after the removal of the lamina. *Image source:* http://www.neurotexasinstitute.com/about-neurotexas-institute/contact-us.aspx.

In retrospect, though, it is likely that substantial contributing factors to mortality following lumbar laminectomy in the 19th century was the lack of modern anesthetic techniques, pain control, and the predating of the widespread use of antiseptic technique. Infection locally or systemically was not uncommon. Prior to the development of antibiotics, systemic infections were associated with high rates of mortality.[5]

However, despite the initial difficulties, there were successful outcomes reported, including a man who received a laminectomy for lower extremity weakness after falling off a horse and sustaining spinal trauma. He regained partial neurologic function. This case, performed by Dr. Alban G. Smith in 1829 in Kentucky, is one of the earliest reported success stories.[6] As more experience was gained, the laminectomy procedure gained acceptance. It was generally described in association with conditions of infection, tumor, or fracture. These pathologic entities were well understood from a historical context given the medical understanding of these conditions. However, the most common indications to perform a laminectomy, for spinal stenosis or lumbar disc herniation, were just beginning to evolve.

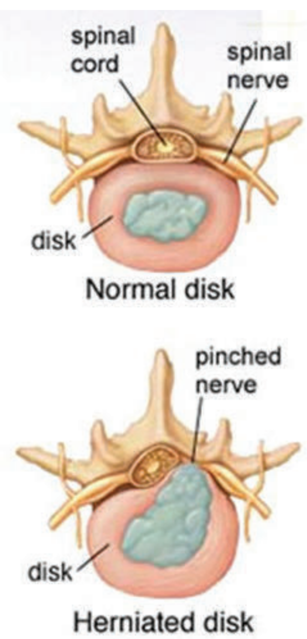

Figure 3. Herniated disc compressing a nerve root. Image source: http://www.spine.md/herniated-disc.

Today, the surgical laminectomy with excision of herniated disc is one of the most common, if not the most common, spinal surgeries performed. Eliminating pressure on a nerve root from a herniated disc or a bone spur has an outstanding track record of pain relief and return to function. During the early history of lumbar decompression for disc herniation, the pathophysiology of the herniated disc was not completely understood. Early reports from pathologists suggested that a "chondroma" or benign cartilage tumor was being removed from the spine.[7] Now we understand that it is actually a ruptured fragment from a degenerating intervertebral disc that causes neural compression and pain. The laminectomy is required to remove the offending disc fragment, a procedure that has an excellent track record.

Over the course of time, the laminectomy has evolved. In the 1930s, the first case report by Mixter and Barr was published in the New England Surgical Society regarding the excision of a herniated disc.[8] Hemilaminectomy, laminaplasty, laminotomy, and others are all variations on a theme, expanding upon the initial idea of lumbar spinal decompression. While too numerous to detail in this article, from the 1930s until the present time the laminectomy has morphed into various adaptations. Despite terminology differences, the laminectomy or lumbar decompressive procedure maintains its role as a "workhorse" procedure in spinal surgery.

As the laminectomy gained popularity, surgeons began to use the microscope to perform laminectomies and explore nerve roots. This was first reported in the late 1960s, ushering in a world of "microsurgery" involving the lumbar spine.[9]

One of the pioneers of modern day lumbar microsurgery was Dr. John McCulloch. Prior to the advent of microsurgery, most lumbar laminectomy procedures involved a midline surgical incision with complete release of the lumbar paraspinal muscles from the midline spinous processes, followed by a formal open laminectomy. For better visualization, surgeons typically wore loupes. Dr. McCulloch introduced the concept of anatomic segments to determine location intraoperatively and correlate region of pathology on preoperative MRI scanning.[10] The improvement in the understanding of local anatomy, including the relationship of the inferior pedicle to the disc space, allows the surgeon to minimize disruption of soft tissues around the spinal segment by focusing on the least amount of bone necessary to remove to expose a herniated disc fragment. This led to decreasing the length of the surgical incision, a significant transition from the long, open midline incision to the shorter, targeted microsugical incision. Dr. McCulloch's contributions to lumbar microsurgery are numerous; a commonly used lumbar surgical retractor system bears his name. While he was not the first to utilize the operating microscope, he was instrumental in converting a number of surgeons to using it.[11]

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Foley and Smith developed the "microtubular discectomy."[12] This idea expanded upon the ideas of lumbar microsurgery, but added an element of tubular dissection to limit soft tissue injury and target neural compressive pathology. The microtubular system involves using a set of dilating tubes under direct fluoroscopy to access the posterior spinal elements. A small stab incision is made in the skin and fascia and the initial dilator is introduced and "docked" on the appropriate posterior spinal landmarks and confirmed fluoroscopically. Progressively larger tubes are then placed over each other until the final tube diameter is decided upon, anywhere from 14mm to 20 mm typically, although it could be larger. The tube is then anchored in placed to the bed via an anchoring arm. The microscope is brought in to the assist the surgeon with visualization and then a formal laminectomy or exposure of the targeted nerve root in question is performed, and the pathology is treated through the anchored tubular retractor.

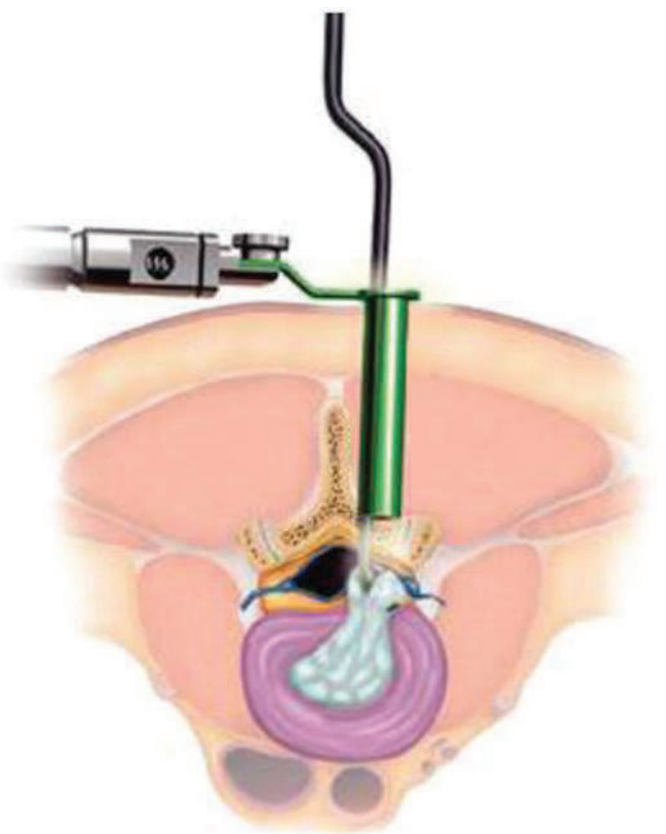

Figure 4. Tubular retractor system used to remove a herniated disc. *Image courtesy of Medtronic, Inc.*

Another technique for limited lumbar decompression—the endoscopic lumbar discectomy emerged. In 1975, Hijikata was the first surgeon credited with percutaneously removing disc, essentially through a tube.[13] Lumbar endoscopic discectomy involved using an endoscope through working portals with instruments to remove bone spurs or herniated fragments of disc under direct visualization. Dr. Anthony Yeung developed the most widely used working channel endoscope in 1997.[14] It basically involves one portal system. Through the portal the surgeon can work with instruments, directly visualize anatomy, and irrigate/suction tissue simultaneously. The benefit of this technique is minimal tissue disruption with very small percutaneous incision. The access is through a posterolateral portal, making treatment of foraminal and extraforaminal disc herniations ideal, although central and larger herniations within the canal can be treated via endoscopic discectomy as well.

Today, all types of techniques for lumbar laminectomy with or without discectomy are utilized. These include formal open laminectomy, endoscopic discectomy, open discectomy with use of the microscope, and tubular microdiscectomy, to name a few. The procedure is so efficacious that it is difficult to measure one technique as being superior to another. Surgeon training and bias likely plays a role in the particular technique utilized. Less invasive techniques have a shorter initial recovery period, although longer term outcomes with each technique appear largely equivalent.

One of the most significant advances paralleling the development of smaller incisions has been the transition of most lumbar laminectomy or decompressive

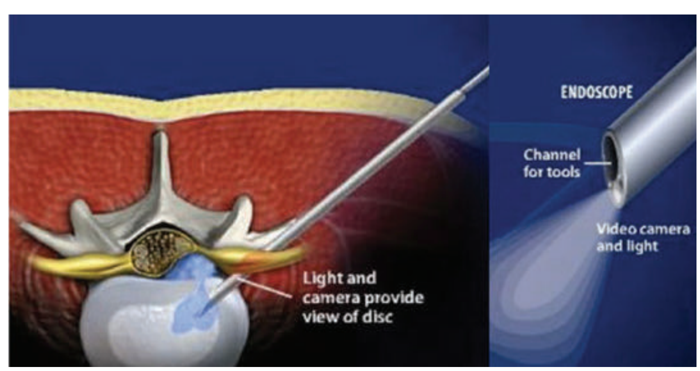

Figure 5. Laminectomy performed through an endoscope. *Image source:* http://www.resurgensspine.com/jeffords/endoscopic-spine-surgery.php

procedures from hospital to outpatient setting. Typically done in a hospital setting, it was not unusual in some settings in the 1980s and 1990s to stay in the hospital for 2 or 3 days following routine microscopic discectomy procedure. Formal laminectomy patients may have been in the hospital for up to a week at times. Now, most of these procedures are done on an outpatient basis, and some are even performed in free standing surgery centers.

Truly, the lumbar laminectomy procedure has evolved substantially in the last one hundred years. Understanding of anatomy and pathoanatomy has had much to do with this. Ingenuity and engineering have played a role in further developing techniques which allow for minimal, less invasive access to the lumbar spine while still allowing for the appropriate and necessary neural decompression. The microscope has added tremendous illumination and visualization for working in small, confined spaces. Undoubtedly, lumbar decompression will continue to evolve to improve outcomes for patients with symptomatic nerve root compression.

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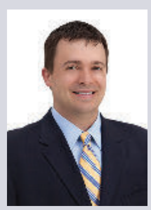

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Sacroiliac Dysfunction

Michael W. Hasz, M.D., F.A.C.S.

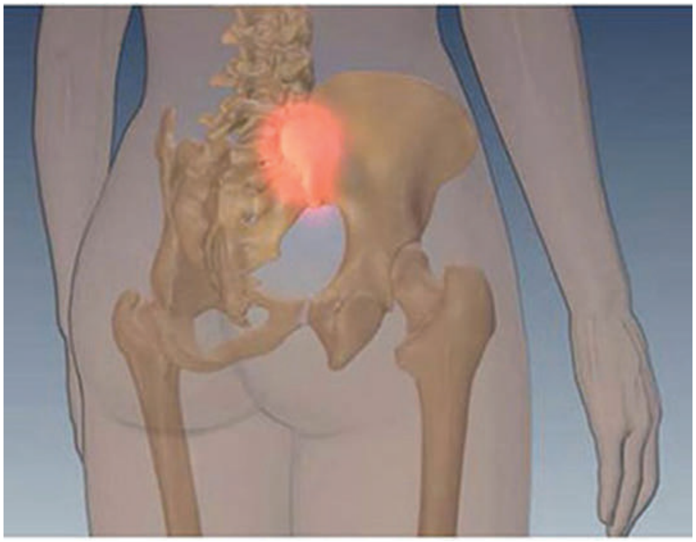

Figure 1. Pain from the sacroiliac (SI) joint. *Image source:* http://www.sijoint.com.

The sacroiliac (SI) joint has been known to be a pain generator for decades. Diagnosing and treating sacroiliac dysfunction was very common in the early 1900's, but fell out of favor when the diagnosis of lumbar herniated discs became very popular. In 1934, Mixter and Barr[1] published an article in the *New England Journal of Medicine* that caused a shift in focus from evaluating back pain accompanied with pain that radiated into the extremities with a multifaceted approach, particularly including the sacroiliac joint, to a concentration on lumbar radiculopathy and disc herniations. Over the ensuing forty to fifty years, much of the focus of patients with back and leg pain was targeted toward disorders of lumbar discs. However, the diagnosis of sacroiliac dysfunction always lingered in the background.

Over the last ten to fifteen years, the sacroiliac joint as a potential cause of back pain and leg pain resurfaced as a useful diagnosis. This likely occurred due to a significant number of patients, up to 20% or more, who did not have any significant resolution of their symptoms when treating only their disc related disorder. In the search for other potential causes of patients' back and leg pain, the sacroiliac joint came back into awareness.

Many surgeons began revisiting the sacroiliac joint as a cause of pain. To help improve the diagnosis of sacroiliac dysfunction, algorithms have been provided in the American Academy of Orthopaedic Surgeon's updates for low back pain, articles have been published describing sacroiliac dysfunction after lumbar fusion, and further diagnostic tests including SI joint arthrograms and other provocative tests have been developed. Additionally, further refinement of surgical procedures has allowed for more precise treatment of sacroiliac dysfunction. There have been over 200 different procedures described for treating patients with sacroiliac dysfunction. The vast majority describe some type of fixation and/or fusion to

Figure 2. Pain from the SI joint resembles pain from a disc herniation. *Image source:* http://www.sijoint.com.

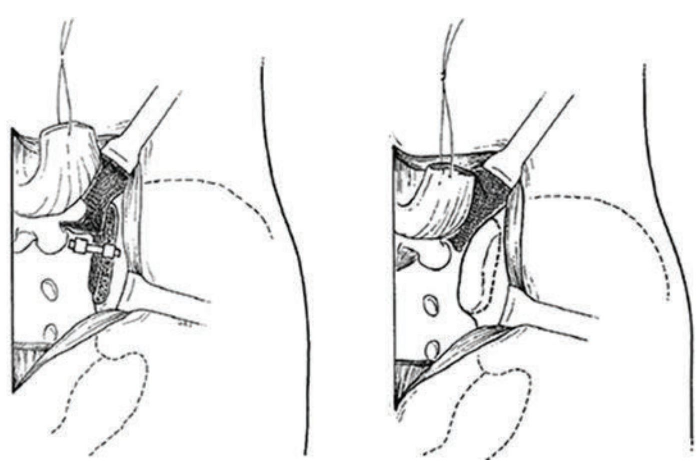

Figure 3. Traditional (open) SI joint fusion. *Image source:* http://www.sijoint.com.

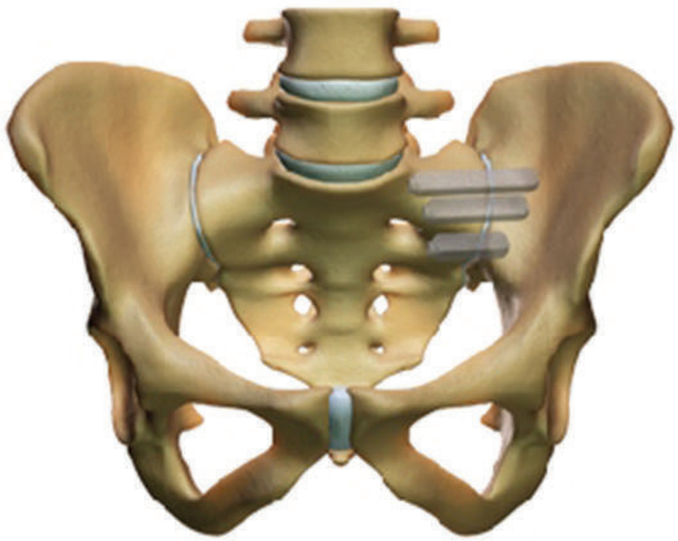

Figure 4. SI joint fusion with minimally invasive implants. *Image source:* http://www.sijoint.com.

treat patients with this disease. New devices allow for a minimally invasive approach to fuse the sacroiliac joint. It is possible to fuse the sacroiliac joint through small incisions with minimal damage to the surrounding tissues. Previously, sacroiliac joint fusion was done with large incisions and substantial disruption of the surrounding tissues.

We indeed have come back from the past into the future, and the future is now. Ninety to one hundred years ago, the diagnosis of sacroiliac dysfunction was part of the differential diagnosis for patients with back and leg symptoms. Once lumbar disc herniations and other disc pathology became popular, sacroiliac joint was nearly forgotten for many years. Recently, with further advances, sacroiliac dysfunction has returned as part of our awareness in treating patients with back and leg symptoms.

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Segmental Fixation of the Cervical Spine

Christopher H. Comey, M.D.

The human cervical spine, or neck as it is more commonly known, consists of seven vertebrae and is an amazingly complex and efficient system for supporting the head while allowing the eyes to be moved in any direction to engage a visual target. It is worth noting that the cervical spine of a giraffe has exactly the same number of vertebrae as its human counterpart. As a system of joints, bones, and ligaments, the cervical spine is subject to a whole range of pathologic conditions. Sprains, fractures, infections, and tumors can all affect this most intricate aspect of the human skeleton.

Figure 1. An artists rendering of an ancient attempt at treating of spinal column. *Image source:* Golden Mirror of Medicine, Ciba periodical 1959;94:8.

Since the days of early human history, physicians and surgeons have needed to treat diseases of the human spine. In certain instances, a portion of the human spine becomes damaged to the point that it requires surgical stabilization. It should be noted that the principles of fixation in the human spine closely mirror those used in construction, engineering, and building. As the discipline of spinal surgery has progressed, the instruments and implants have markedly improved, but the physical principles have remained constant.

At this point, it is worth spending some time on several key concepts related to surgical treatment of cervical spine problems. Fixation is best understood as a means of anchoring one or two bones together. Fixation is best thought of as an internal brace or splint. Successful spine surgery requires bone healing, in addition to fixation. Bone graft material is either gathered from the spine itself or taken from a part of the pelvic ring, known as the iliac crest. Bone healing across one or more joints is known as arthrodesis. No matter how advanced our fixation techniques become, successful surgery usually involves getting several bones to heal together. Independent of the hardware aspect of surgery, bone healing and bone grafting require meticulous attention to detail on the part of the spine surgeon.

In terms of the cervical spine, certain problems require surgical correction from the anterior (front) approach, while others can be solved from the posterior (back) approach. Some very complex conditions require that the surgeon operate from both the front and back during the same procedure. As imaging techniques and anesthesia have become more sophisticated, surgeons have been able to treat an increasing number of conditions previously referred to as "inoperable."

The history of the evolution of the specialized implants, or hardware, used to correct problems in the cervical spine is fascinating. Before the advent of implants to internally fixate the spine, surgeons had to rely on bulky and often ineffective external braces or casts. As the industrial world advanced, better materials became available to spine surgeons. In the early 1940s, surgeons

Figure 2. The Minerva cast was one of the most popular external braces used to treat spinal deformities of neck and back. *Image source:* http://mmm.lib.msu.edu/record.php?id=2227#images

Figure 3. Anterior-posterior view of posterior cervical wire figure-eight construction. *Image source:* http://medapparatus.com/Gallery/gallery.html

began to use stainless steel wire to provide fixation across one or more joints in the spine. This technique was found to be limited, however, in that it was difficult to rigidly fixate more than one level of the spine. Using a very detailed technique, Dr. Henry Bohlman modified previous techniques to introduce the triple-wire technique. This rapidly became the most popular fixation technique. For its time, it represented a significant advance in technique. It allowed the surgeon to rigidly fixate more than one level of the cervical spine. Surgeons soon found however that wire was difficult to work with and would frequently break. These limitations ultimately motivated surgeons to look for better, stronger techniques to fixate the spine. One such advance substituted cables for wires. Cables, which represent a number of small diameter wires wound around each other, offered the advantages of superior strength, improved handling characteristics, and resistance to breakage. For surgeons accustomed to broken wires, the cables were a welcome advance. Unfortunately, surgeons soon came to realize that cables shared the limitation of wires in that they were really best suited for fixation of a single joint in the cervical spine.

In the 1970s and 1980s, a number of European and American spine surgeons began to experiment with the idea of actually fixating one or more levels of the spine with screws and plates. Like the plates used by carpenters to support critical joints, these plates had a series of holes through which a screw could pass and subsequently anchor into a part of the posterior spine known as the lateral mass. These plates allowed the surgeons to span multiple levels of the spine with more rigid fixation. The technique to apply the screws and plates was also easier to learn and carry out than the

Figure 4. X-rays of lateral mass screws and plates. Front view on left, side view on right. *Image source:* Ronald W. Lindsey, MD, Theodore Miclau, MD. Posterior Lateral Mass Plate Fixation of the Cervical Spine. *J South Orthop Assoc.* 2000;9(1).

wiring or cable techniques. The principal limitation with this important technique was the lack of mechanism to anchor the screw and plate together. Despite this limitation, the technique quickly replaced the use of wires and cables as the standard. Whereas surgeons had difficulty precisely reproducing some of the more advanced wiring techniques, the so-called lateral mass plates were more straightforward for surgeons to learn and consistently perform. It was these lateral mass plates that ushered in the true era of segmental fixation in the cervical spine.

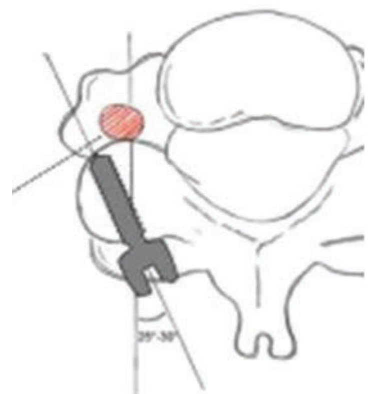

Figure 5. Schematic of the lateral mass of the human cervical spine with a lateral mass screw in place.

The next significant advances in hardware used for segmental fixation in the cervical spine are owed to improvements in materials and manufacturing

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techniques. To understand this transformation, a brief detour to the human lumbar spine is in order. In the 1970s and 1980s, surgeons were beginning to use screws to fixate the larger bones found in the lumbar spine. The bony corridor used to access the lumbar vertebral body is known as the pedicle, hence the name pedicle screws. Unfortunately, the use of pedicle screws was sidelined by screw breakage. This problem was quickly addressed through improved use of metal alloys and better engineering. However, the screws themselves were very nearly abandoned due to the most American of activities: the class action law suit. After their tumultuous journey through the American legal system, it was realized that pedicle screws could offer real benefit to certain patients. It was at this point that engineers began to look at the concept of placing what amounted to miniature pedicle screws into the lateral masses of the cervical spine. Unlike the technique employed with plates, the screws would be anchored to the bone, as well as rigidly connected to each other through a rod. The screws were further modified to consist of a bone screw with a tulip-shaped connector attached to it. This permitted the screw head to adjust its position to capture the rod. This advance ushered in the current state-of-the-art segmental fixation for the cervical spine.

True segmental fixation offers the surgeon the ability to rigidly affix a screw and rod to the spine over multiple levels. This more rigid fixation allows surgeons to fix deformities and injuries that otherwise would have been all but untreatable in years past. A more reproducible and rigid system of fixation produces better rates of bone healing or arthrodesis. These newer systems are also designed in a modular fashion such that they can be linked to systems anchoring the thoracic spine or even up to the skull. As experience with these more advanced systems grows, engineers are continually making improvements. These improvements are driven by feedback from experienced surgeons as well as from patients themselves. The role of any segmental cervical fixation system is to provide the surgeon with the most options to safely fixate the cervical spine across areas of disease or injury and allow his or her patient to make the best possible recovery.

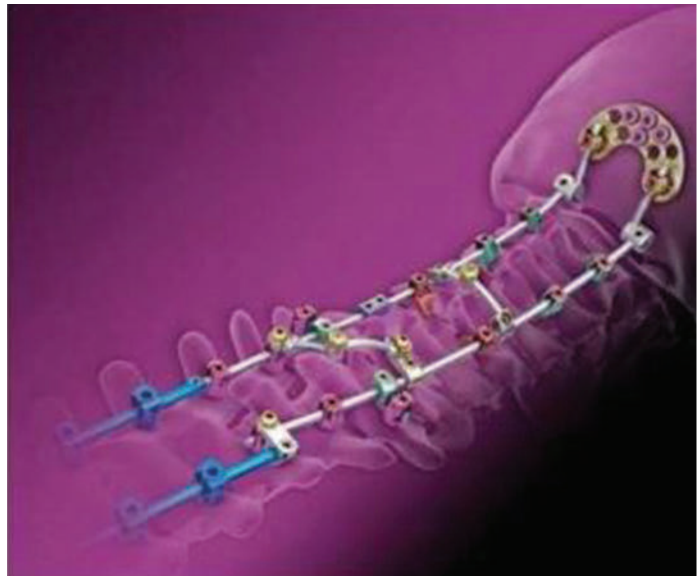
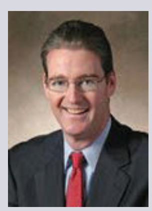


Figure 6. Illustration of cervical screw–rod system connecting to skull (on right) and thoracic spine (on left). *Image courtesy of Medtronic, Inc.*



Christopher H. Comey, M.D.

Dr. Comey is a neurosurgeon in Springfield, Massachusetts affiliated with New England Neurosurgical Associates. He completed his residency at the University of Pittsburgh where he learned the most advanced techniques for surgical treatment of aneurysms, tumors, head injury and spinal disorders. He completed his fellowship at Emory University where he studied all aspects of surgical treatment of spinal disease and implant design. Dr. Comey focuses on cutting-edge methods for the treatment of spinal conditions. He has authored 17 peer-reviewed publications as well as one book chapter, holds a United States patent for a spine surgery device, serves as an investigator in several FDA studies evaluating new devices and procedures, and continues to lecture and teach surgical techniques to surgeons around the country. His practice has encompassed all aspects of neurosurgical care with a special emphasis on minimally invasive surgical techniques as well as the treatment of complex spine conditions.

Emerging Imaging in Musculoskeletal Medicine

Niteesh Bharara, M.D., D.A.B.P.M.R.

Since the discovery of x-rays in the late 1800s, there have been substantial advances in the field of musculoskeletal imaging. So, just what is this type of imaging? Well, for starters, it involves the diagnostic evaluation of the musculoskeletal anatomy.

The initial use of x-rays, as far back as the 1890s, was to assess for broken bones; however, the subsequent development of both computerized tomography (CT scans) and magnetic resonance imaging (MRIs) allowed for better, more sensitive evaluation of the musculoskeletal system. More recently, ultrasound has emerged and gained widespread acceptance for the evaluation of the musculoskeletal system. Diagnostic ultrasound has its origin in sound navigation and ranging (SONAR) and involves oscillating sound pressure waves to visualize muscles, tendons, and many of our internal organs. Musculoskeletal ultrasound can serve as an excellent diagnostic modality for a musculoskeletal physician. The structures which are commonly and easily visualized as well as evaluated include: tendons, nerves, muscles, and osseous structures.

Although an MRI is much more frequently ordered, each imaging study has its advantages and disadvantages. Ultrasound has significant benefits and has one particular advantage over an MRI—it is much less expensive. It is also much more patient friendly and more easily tolerated compared to an MRI. Claustrophobia is commonly encountered with MRI scans and is not encountered in an ultrasound examination. MRI and ultrasound can both examine large areas of the body with extended field of view; however, ultrasound examinations are dynamic studies. For example, the affected part can be imaged in real time, observing for pathologic movement in tendon, bursa, muscles, or joints. MRI does not allow for this and only provides a static picture of the anatomy. Since the ultrasound evaluation is dynamic, the structures evaluated can be changed and revised during the study based on results. Ultrasound evaluations also allow for immediate results, and that in turn allows for treatment plans to be developed at the time of imaging.

Ultrasound can also be utilized for interventional procedures. Compared to the use of fluoroscopic and CT guidance, ultrasound has many advantages.

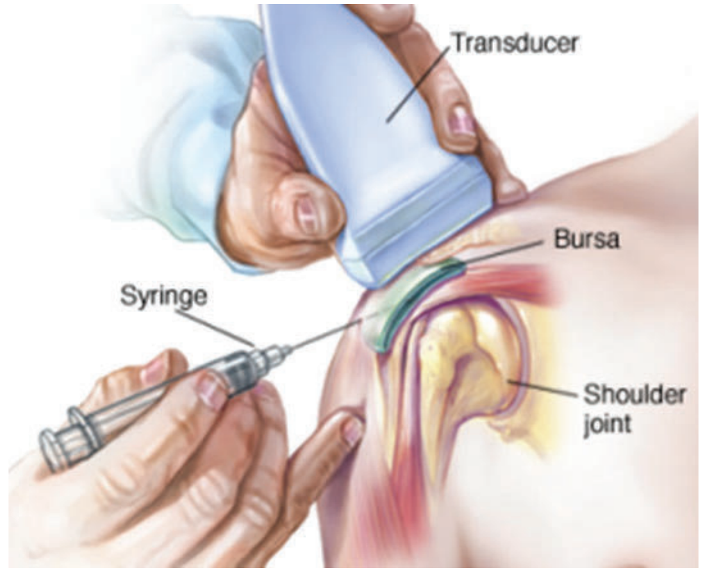


Figure 1. Depiction of ultrasound-guided needle injection to reduce harmful radiation exposure. *Image courtesy of the Mayo Clinic.*

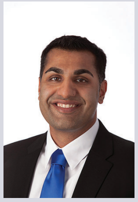
Fluoroscopic and CT guidance are currently the most frequently modalities ~~used~~ to localize needle placement during an interventional treatment such as a tendon injection. Both of these modalities use ionizing radiation to visualize structures. Fluoroscopy does not visualize soft tissues, but instead relies on bony landmarks and often necessitates iodinated contrast dye in order to prevent inadvertent intravascular placement and to confirm placement. Contrast dye is used to assess placement of the needle in soft tissue, but some patients may be allergic to contrast and would need prophylactic medication to prevent a reaction. Ultrasound, on the other hand, does not utilize ionizing radiation, so contrast would not be needed. ~~And~~ thus, various soft tissues and joints can be directly entered, aspirated, or drained. It has been estimated that approximately 29% of knee injections may miss the joint without guidance. However, with the use of ultrasound guidance, the needle can be visualized when entering the joint space.

It is important to note that diagnostic ultrasound has many limitations as well. It is dependent on body habitus, and in certain situations, it may not be able to penetrate excessive soft tissue in order to evaluate deep structures. The benefit of the ultrasound evaluation is operator dependent and requires performance by an experienced clinician. Without this, optimal image acquisition will not be obtained, and pathology may be missed or misinterpreted.

There are current estimates stating that approximately 30% of all musculoskeletal injuries are muscular; ultrasound is an excellent imaging modality to detect and classify these types of injuries. Injuries such as rotator cuff tears, hamstring tears, and other muscular injuries can be detected using this diagnostic study. MRI is the most useful modality when assessing joint pathology; however, ultrasound is the best diagnostic modality to assess for joint effusions. Nerves can also be studied using diagnostic ultrasound. Nerve impingements such as carpal tunnel syndrome can be directly visualized to assess the severity of the impingement.

Diagnostic ultrasound is an excellent imaging modality to assess musculoskeletal pathology, yet is often under-used. Recent improvements and advances in ultrasound technology make it much more accurate and dynamic than other modalities such as CT and MRI. Ultrasound is easily tolerated, low cost, highly dynamic, and portable which makes it an ideal modality for musculoskeletal physicians to use in diagnostic and interventional purposes.

Niteesh Bharara, M.D., D.A.B.P.M.R.



Dr. Bharara is a board certified, fellowship-trained physiatrist and interventional pain management specialist at the Virginia Spine Institute. Prior to joining the pain management team at VSI, Dr. Bharara acted as Chief Resident and served as Clinical Instructor during his residency at Temple University Hospital in 2011–2012. He was awarded a select fellowship and subsequently named a Senior Fellow at Temple University Hospital's top ACGME-accredited fellowship training program in the subspecialty of Interventional Spine & Pain Management. Dr. Bharara brings multifaceted experience to the team and specializes in treating musculoskeletal patients, performing electro-diagnostic procedures, and administering peripheral and spinal injections. His philosophy promotes the practice of innovative and safe interventional pain management techniques for the diagnosis and treatment of pain and related disorders. With this, he also exemplifies a compassionate approach with his patients to alleviate pain, restore maximum function and improve quality of life. Dr. Bharara is Vice-Chairman of the Young Physicians Section of the American Society of Interventional Pain Physicians and is affiliated with American Academy of Physical Medicine & Rehabilitation.

Back to the Future to Realign the Spine

Michael W. Hasz, M.D., F.A.C.S.

The treatment of spinal deformities has changed dramatically over the past few generations of treatment. However, the fundamental goals have remained essentially unchanged. The primary goals of treatment for a deformity, such as scoliosis, include reducing or realigning the curve to a more normal pattern, decreasing the cosmetic effect of spinal curvature, and maintaining and protecting the internal organs such as heart and lungs.

The normal alignment of the spine is evaluated along three planes: the sagittal (looking at the spine from the side), coronal (looking at the spine from the front or back), and the axial (looking at the spine from top to bottom) planes. A correctly aligned spine has normal curves in the sagittal plane but no curves in the coronal and axial planes. When a deformity exists in a plane (such as scoliosis—with curves from side to side in the coronal plane), it typically also creates deformity in the other planes. For example, scoliosis causes rotation of the spine in the axial plane.

Many years ago, prior to surgical intervention, the initial treatment for patients with deformities was to place them in casts and hope that traction, casts, or other pressure on the outside of the body could help realign the spine or at least decrease the curves. The next phase in spinal treatment included putting bone graft on the spine while the patient is placed in a cast hoping that the spine would then fuse in the correct position.

Figure 1. Anteroposterior x-ray view of scoliosis in patient.

The first phase of the more modern treatment of spinal deformity included the surgical implantation of Harrington rods. The majority of the treatment was focused upon correcting the side to side curves known as the coronal curves. At that time, the instrumentation was not strong enough or designed for realigning the curve of the spine from the top-down or the rotation of the spine in the axial plane; nor was it sophisticated enough to deal with the front-to-back curves in the sagittal plane. Basically, the Harrington rod system put a distraction force at both ends of the curve in order to try to straighten out the coronal curves. Unfortunately, this instrumentation did not change the sagittal curves and can lead toward a flat back deformity. Often, the Harrington rods did not address the curvature so that any rotation as often seen by the rib hump was not corrected.

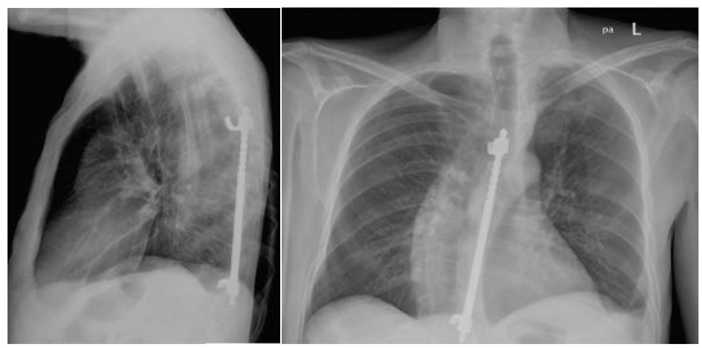


Figure 2. Anteroposterior (a) and lateral (b) x-ray views of Harrington rod system in the thoracic spine. *Image source:* chestdevices.com.

At that time, some workarounds used to remedy the cosmetic deformities as well as the pulmonary dysfunction related to the rib humps, included removing some ribs and doing a thoracoplasty. While the Harrington rod system was an advance, there were further steps required.

The next step included doing surgery from the front (anterior) and back (posterior) of the spine. Releasing the discs and ligaments at the front of the spine could make the spine more flexible, allowing for greater correction and could begin to address some of the rotational deformities of the spine. While these surgeries definitely improved the radiographic alignment of the spine, they often required very large incisions, created other comorbidities such as decreased pulmonary function, and required an extended recovery.

Segmental fixation constituted the next advance for treating scoliosis, including idiopathic and degenerative scoliosis. This approach overall means screws or hooks at each vertebral body level within the range

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of levels being treated. The main advantage of segmental fixation (compared to Harrington rods) ~~is~~ that it allow~~s~~ for local forces to be placed at each portion of the curve. With smaller forces at each local area of the spine, not only could the coronal curve be addressed, but the sagittal curve ~~can~~ also be treated. Additionally, the rotation of the vertebral body could also be corrected. The ability to address all of these parts of the spinal curve allow~~s~~ for protection of pulmonary function and decompression, also making more room for the abdominal organs.

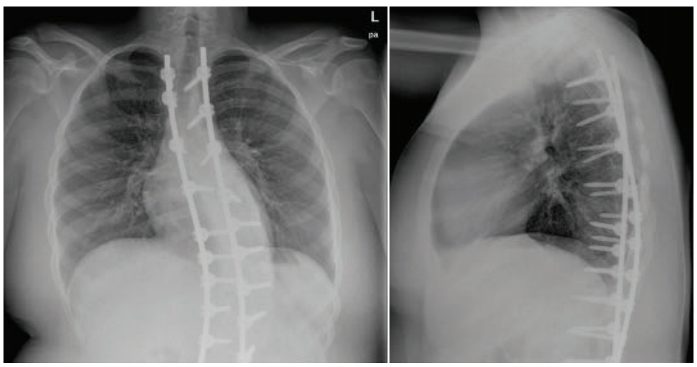

Figure 3. Anteroposterior (a) and lateral (b) x-ray views of segmental fixation in the thoracic spine. *Image source:* chestdevices.com.

Initially, surgeons using this technique still combined some anterior releases by performing anterior surgeries in conjunction with the posterior surgeries. As the instrumentation improved, fewer anterior releases were required in order to achieve the curve improvement.

While surgeons implanted segmental fixation available from the posterior approach, they also explored implanting segmental fixation from an anterior approach. Some advantages, particularly at the thoracolumbar junction, allowed for fusing fewer segments while still obtaining significantly improved correction. However, the down side of the anterior surgery still often included a large incision which could affect scar tissue as well as some pulmonary function.

Today, a significant number of scoliosis cases are able to be treated from a posterior approach, particularly in the thoracic spine to address the curve. Hence, a major advance in deformity surgery stemmed from the development of segmental fixation which applied small amounts of forces at multiple levels of the spine and allowed for a significantly improved correction, as well as significantly improved healing rates and decreased amount of non-unions identified in the spine.

The next phase in the advancement of spinal deformity surgery is currently being explored at multiple centers and includes using some minimally invasive surgical (MIS) techniques to see if segmental fixation and the more focal, small incisions can be used in deformity surgery, allowing even smaller amounts of fusions. This approach relies on segmental fixation, as well as the tools that can be now used from the anterior approach through a much smaller incision in order to obtain more correction, or at least adequate correction through a smaller surgery, requiring less recovery overall.

Some questions at this point include how many levels of surgery are required and how much deformity correction really is needed. There may be some compromises made by using some anterior surgery approaches and allowing more curve to remain, but still maintaining good balance and allowing flexibility of the spine to remain.

So the idea of going back to the future by using some anterior surgery approaches is very promising. Returning to some anterior approaches with smaller MIS procedures is also very promising. All of these ideas allow for addressing spinal deformity with smaller surgeries and more modern techniques.

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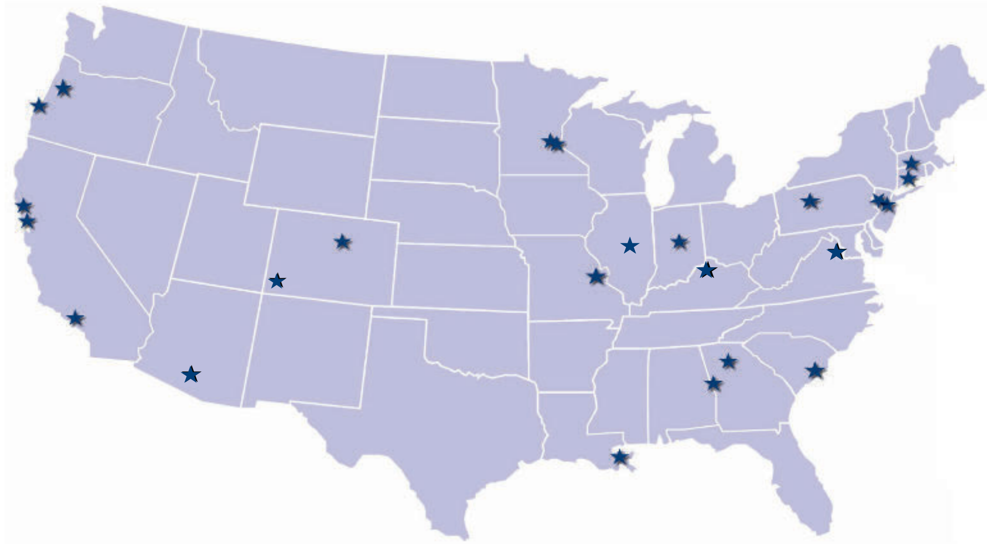
Dr. Hasz is a spine surgeon at the Virginia Spine Institute. He is board certified by the American Board of Spine Surgery, a Fellow in the American Academy of Orthopaedic Surgeons, and a member of both the American Association of Orthopaedic Surgeons and the North American Spine Society. He was Chairman of the Department of Orthopaedic Surgery and Director of Spinal Surgery at the Andrews Air Force Base/ Malcolm Grow Medical Center in Maryland. He currently holds an appointment as Clinical Instructor of Orthopaedic Surgery and Assistant Professor of Surgery at the Uniformed Services Health Science University in Bethesda, Maryland.

Spinal Research Foundation Research Partners

The Spinal Research Foundation has named 26 Research Partners across the country that share one core mission: improving spinal health care through research, education, and patient advocacy. These centers offer the best quality spinal health care while focusing on research programs designed to advance spinal treatments and techniques.



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Spine Surgeon

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Thank You!

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